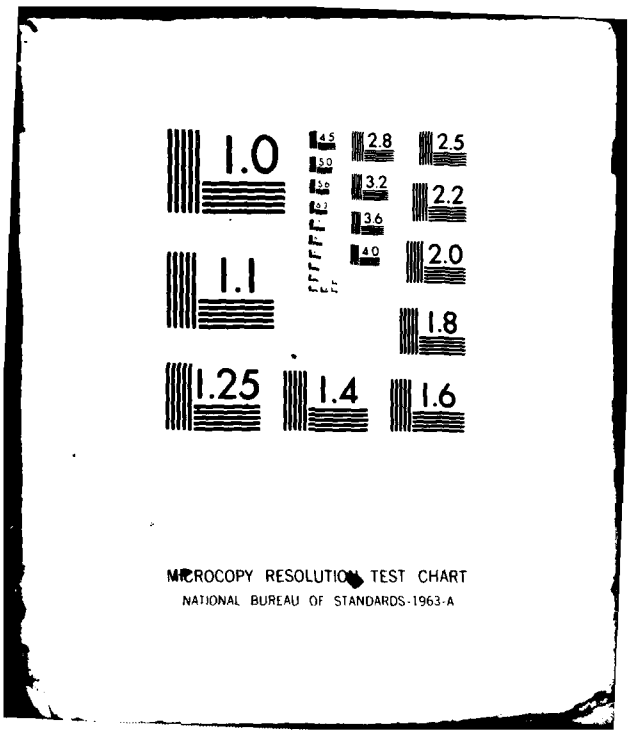
AD-A087 254 TEXAS UNIV AT AUSTIN APPLIED RESEARCH LABS F/G 9/2
USER'S MANUAL FOR NEMESIS AND PLMODE.(U)
MAY 80 R GONZALEZ, S G PAYNE N00014-79-C-0263
UNCLASSIFIED ARL-TM-80-6 NL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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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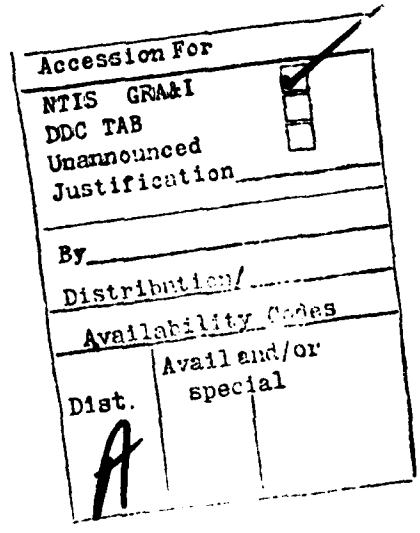
TABLE OF CONTENTS



I. INTRODUCTION

The normal mode model, NEMESIS, was designed and implemented at the Applied Research Laboratories, The University of Texas at Austin (ARL:UT), to aid in the investigation of low frequency, range invariant, acoustic propagation effects. The mathematical basis and numerical scheme of this model are described by Gonzalez and Hawker (1980). NEMESIS computes the eigenvalues and normal modes of the depth separated acoustic wave equation. Group velocities and modal attenuation terms are also computed. Propagation loss and velocity potential for a source and receiver at a given range can be calculated from these quantities (Gonzalez and Hawker, 1980). A computer model, PLMODE, was designed to perform these computations, and the computer code for both NEMESIS and PLMODE was prepared for export to other research laboratories. This report is designed to accompany this software and to assist persons who wish to use it. The contents include descriptions of the modeled environment, the input data and their format, and the output produced by the models. An explanation of the diagnostic messages that may arise during execution of the models is also included. Estimates of memory requirements and execution times are given along with sample data sets and their resulting output.

Although it provides information beyond the scope of a user's manual, an appendix, "Installation Information," has been added to this document to aid in the retrieval of the software from the magnetic tape on which it was written for export.

II. NEMESIS: DOCUMENTATION

The following chapter is extracted from the computer model NEMESIS.

NEMESIS ARL:UT NORMAL MODE MODEL
VERSION 1.2 FEBRUARY 1980

DESIGNED AND IMPLEMENTED BY

RUTH GONZALEZ

DOCUMENTATION FOR NEMESIS IS GIVEN IN

THE ACOUSTIC NORMAL MODE MODEL NEMESIS

BY

RUTH GONZALEZ AND KENNETH F. HAWKER

ARL:UT TECHNICAL REPORT ARL-TR-80-13

AND

USER'S MANUAL FOR NEMESIS AND PLMODE

BY

RUTH GONZALEZ AND SUSAN G. PAYNE

ARL:UT TECHNICAL MEMORANDUM ARL-TM-80-6

THE APPLIED RESEARCH LABORATORIES

THE UNIVERSITY OF TEXAS AT AUSTIN

SPONSORED BY NORDA CODE 520, NSTL STATION, MISSISSIPPI 39529

MATHEMATICAL AND PHYSICAL DESCRIPTION

NEMESIS IS LOW FREQUENCY, RANGE-INVARIANT, WAVE THEORY NORMAL MODE MODEL. IT WAS DESIGNED TO COMPUTE EIGENVALUES AND NORMAL MODES IN A HORIZONTALLY STRATIFIED DEEP OCEAN WITH SINGLE CHANNEL PROFILES AND MULTIPLE FLUID SEDIMENT LAYERS OVERLYING A SUBSTRATE. SOUND SPEEDS IN THE WATER AND SEDIMENT VARY WITH DEPTH. THE DENSITY IS CONSTANT WITHIN EACH LAYER. THE LAST LAYER IS A HOMOGENEOUS, SEMI-INFINITE, FLUID OR SOLID SUBSTRATE, I.E., THE COMPRESSIONAL AND SHEAR SPEEDS AND DENSITY REMAIN CONSTANT WITH DEPTH. SOUND SPEEDS AND DENSITIES CAN BE DISCONTINUOUS AT LAYER INTERFACES. THE MODEL NUMERICALLY COMPUTES THE DISCRETE EIGENVALUES AND EIGENFUNCTIONS, OR NORMAL MODES, OF THE DEPTH SEPARATED ACOUSTIC WAVE EQUATION FOR THIS TYPE OF ENVIRONMENT. THE CONTINUOUS PART OF THE SPECTRUM OF THE SOLUTION IS IGNORED. GROUP VELOCITIES ARE ALSO COMPUTED.

DEPTH EQUATION

$$(D^2 / DZ^2)\, U_N + (K^2(Z) - K_N^2)\, U_N = 0$$

WHERE U_N IS THE EIGENFUNCTION
K_N IS THE EIGENVALUE
$K(Z) = 2*PI*F / C(Z)$
C(Z) IS THE SOUND SPEED
F IS THE SOURCE FREQUENCY

ANY QUESTIONS CONCERNING THE APPLICABILITY OF THE MODEL TO A PARTICULAR SITUATION SHOULD BE DIRECTED TO

KENNETH E. HAWKER
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ON INPUT

THE FOLLOWING RESTRICTIONS ARE IMPOSED ON THE INPUT TO NEMESIS

(1) THERE MUST BE AT LEAST 2 LAYERS (WATER AND SUBSTRATE) BUT NO MORE THAN 10.
(2) ALL DEPTHS MUST BE IN INCREASING ORDER.
(3) DEPTHS AT LAYER INTERFACES MUST BE EQUAL, I.E., THE LAST DEPTH AT THE BOTTOM OF A LAYER MUST EQUAL THE FIRST DEPTH AT TOP OF THE NEXT LAYER.
(4) FIRST SPECIFIED DEPTH MUST BE 0 (AIR-SURFACE INTERFACE).
(5) THE SOUND SPEED MINIMUM IN THE WATER AND SEDIMENTS MUST BE LESS THAN THE SHEAR AND COMPRESSIONAL WAVE SPEEDS IN THE SUBSTRATE.
(6) SHEAR SPEED OF ZERO IN THE SUBSTRATE IMPLIES A FLUID SUBSTRATE AND A NONZERO SHEAR SPEED IMPLIES A SOLID SUBSTRATE. NO SHEAR SPEEDS ARE ALLOWED IN THE WATER OR SEDIMENTS.
(7) THE SHEAR SPEED MUST BE LESS THAN THE COMPRESSIONAL WAVE SPEED IN THE SUBSTRATE.
(8) IF A PRESSURE RELEASE BOTTOM IS SPECIFIED, THERE ARE AN INFINITE NUMBER OF MODES. THE COMPRESSIONAL SPEED IS USED AS THE PHASE VELOCITY CUTOFF, IN THIS CASE, AND IS NOT USED IN THE BOUNDARY CONDITIONS.
(9) FOR SOME DATA INPUTS, DEFAULTS ARE GIVEN IN PARENTHESES. THESE CAN BE INVOKED BY LEAVING THE APPROPRIATE DATA FIELD BLANK OR SETTING IT TO 0.
(10) MAXIMUM NUMBER OF DEPTH-SOUND SPEED PAIRS IS 125.
(11) MAXIMUM MODE WHICH CAN BE COMPUTED IS MODE NUMBER 300.
(12) MAXIMUM NUMBER OF MESH POINTS PER MODE IS 2000. THE NUMBER OF MESH POINTS IN A LAYER IS EQUAL TO THE NUMBER OF MESH INTERVALS IN THAT LAYER PLUS 1.
(13) THE NUMBER OF MESH INTERVALS IN EACH LAYER MUST BE EVEN AND GREATER THAN OR EQUAL TO 4. THERE ARE NO MESH INTERVALS IN THE SUBSTRATE. THE SOLUTION IS ANALYTICALLY COMPUTED IN THAT REGION.
(14) ALL QUANTITIES MUST BE SPECIFIED IN THE MKS SYSTEM EXCEPT DENSITY, WHICH IS IN THE CGS SYSTEM.
(15) THE DEPTHS ASSOCIATED WITH BOTH THE COMPRESSIONAL AND SHEAR SPEEDS IN THE SUBSTRATE ARE THE SUBSTRATE INTERFACE DEPTHS. THE COMPRESSIONAL SPEED IS FIRST AND THE SHEAR SPEED IS SECOND.

INPUT TO NEMESIS IS VIA FORMATTED READ STATEMENTS. EACH ITEM MUST BE POSITIONED IN THE CORRECT FIELD AS GIVEN BY THE FORMAT STATEMENT. INTEGER VALUES AND EXPONENTS MUST BE RIGHT-JUSTIFIED IN THEIR FIELD.

CARD NO	COLUMN NO OF CARD	DESCRIPTION OF DATA	FORMAT
1	1-80	HEADER INFORMATION USED TO DESCRIBE DATA	8A10
2	1-10	SOURCE FREQUENCY IN HZ	F10.3
	11-20	DEPTH WHERE THE INTEGRATIONS ARE TO BE MATCHED; MUST BE IN WATER (DEFAULT IS AT SOUND SPEED MINIMUM IN THE WATER OR MIDDLE OF THE WATER COLUMN. DEFAULT IS RECOMMENDED)	F10.3
	21-30	WAVE NUMBER K1	F10.3
	31-40	WAVE NUMBER K2	F10.3
	41-50	WAVE NUMBER INCREMENT. K1, K2, AND INCREMENT ARE FOR ADDITIONAL DIAGNOSTIC INFORMATION. THE DIFFERENTIAL EQUATION IS INTEGRATED USING THE WAVE NUMBERS K1 TO K2 IN THE INCREMENT SPECIFIED IN COLS 41-50. THE DISCONTINUITY IN THE DEPTH DERIVATIVES OF THE TRIAL MODES IS TABULATED FOR EACH WAVE NUMBER. NOT RECOMMENDED UNLESS TRACING CONVERGENCE OF NUMERICAL PROCESS. ALL THREE QUANTITIES MUST BE POSITIVE TO ACTIVATE DIAGNOSTICS	F10.3
3	1-5	LOWEST MODE NUMBER TO BE COMPUTED (DEFAULT IS 1)	I5
	6-10	HIGHEST MODE NUMBER TO BE COMPUTED (DEFAULT IS TO COMPUTE ALL MODES UP TO MODE NUMBER 300)	I5
4		OPTIONS TO BE USED (1=YES, 0=NO)	
	5	CORRECT SOUND SPEEDS FOR CURVATURE OF EARTH	I5
	10	USE PRESSURE RELEASE SUBSTRATE	I5
	15	SUPPRESS CALCULATION OF HIDDEN DEPTHS; NOT RECOMMENDED	I5
	20	TURN ON DIAGNOSTIC PRINTS AS MODES ARE COMPUTED. NOT RECOMMENDED UNLESS TRACING CONVERGENCE OF NUMERICAL PROCESS	I5
5	1-10	DENSITY OF LAYER	F10.3
	11-15	NUMBER OF MESH INTERVALS IN LAYER (DEFAULT IS MAXIMUM ALLOWABLE)	I5

6A,B..		SOUND SPEED PROFILE IN THIS LAYER	
	1-10	DEPTH	F10.3
	11-20	SOUND SPEED	F10.3
	21-30	DEPTH	F10.3
	. . .	. . .	. . .
	71-80	SOUND SPEED	F10.3
7		BLANK CARD	
		REPEAT CARDS 5-7 FOR EACH SEDIMENT LAYER	
8	1-10	DENSITY OF SUBSTRATE	F10.3
9	1-10	DEPTH OF SEDIMENT/SUBSTRATE INTERFACE	F10.3
	11-20	COMPRESSIONAL SPEED	F10.3
	21-30	DEPTH OF SEDIMENT/SUBSTRATE INTERFACE	F10.3
	31-40	SHEAR SPEED	F10.3

ON OUTPUT

NEMESIS USES FILES LFOUT, LTAPE1, AND LFDIAG AS OUTPUT FILES

ON LFOUT

NEMESIS USES FILE LFOUT TO OUTPUT ALL PRINTED INFORMATION SUCH AS INPUTS AND QUANTITIES THAT WERE CALCULATED IN THE PROGRAM SUCH AS EIGENVALUES, GROUP VELOCITIES, AND ATTENUATION TERMS. THE ATTENUATION TERMS FOR EACH MODE ARE LISTED IN THE FOLLOWING ORDER:

ATTENUATION IN WATER LAYER
ATTENUATION IN FIRST SEDIMENT LAYER
. . .
ATTENUATION IN LAST SEDIMENT LAYER
ATTENUATION IN SUBSTRATE (COMPRESSIONAL)
ATTENUATION IN SUBSTRATE (SHEAR)

ON LFDIAG

NEMESIS USES LFDIAG FOR PRINTED DIAGNOSTIC MESSAGES. CAUTION - IF DIAGNOSTIC PRINT OPTION IS TURNED ON, THIS FILE CAN BE VERY LARGE. THE FOLLOWING ERROR AND DIAGNOSTIC MESSAGES ARE GENERATED BY NEMESIS:

FATAL INPUT ERRORS

ONLY 10 LAYERS ARE ALLOWED

AT LEAST TWO LAYERS MUST BE USED TO RUN NEMESIS

SOUND SPEED ARRAY OVERFLOW

ALL DEPTHS MUST BE IN INCREASING ORDER

DEPTHS AT LAYER INTERFACES MUST BE EQUAL

EACH LAYER MUST HAVE AT LEAST TWO DEPTH-SOUND SPEED POINTS

DEPTH AT AIR-WATER INTERFACE MUST BE ZERO

SOUND SPEED MINIMUM OF THE WATER AND SEDIMENT LAYERS
MUST BE LESS THAN THE COMPRESSIONAL VELOCITY

SHEAR SPEED MUST BE LESS THAN THE COMPRESSIONAL SPEED

IF THE SHEAR SPEED IS NONZERO, THE SOUND SPEED MINIMUM
MUST BE LESS THAN THE SHEAR SPEED

OPTIONS MUST BE SPECIFIED WITH A 0 OR 1

TOO MANY SPEEDS FOR SUBSTRATE

FATAL ERRORS (NUMERICAL AND PROGRAMMING)

INTEGRATION COUNT EXCEEDS MAXIMUM ALLOWABLE, MODE NO =

ALL MATCH POINTS EXHAUSTED, CONVERGENCE NOT ACHIEVED, FOR MODE NO

ERROR IN NUMROV, CALLED FROM INTGR1, IER =

ERROR IN SUBROUTINE INTRP AFTER CALL TO ICSICU

ERROR IN SUBROUTINE INTRP AFTER CALL TO ICSEVU

ERROR IN CALL TO SECANT FOR MODE NUMBER.

ERROR IN COMPUTATION OF RAYLEIGH VELOCITY

ERRORS DETECTED IN IMSL ROUTINES

*** TERMINAL ERROR, IER = FROM IMSL ROUTINE

*** WARNING WITH FIX ERROR IER = FROM IMSL ROUTINE

*** WARNING ERROR IER = FROM IMSL ROUTINE

*** UNDEFINED ERROR IER = FROM IMSL ROUTINE

DIAGNOSTIC PRINTS FOR TRACING CONVERGENCE OF NUMERICAL PROCESS
(FOR MORE DETAILED INFORMATION SEE GONZALEZ AND HAWKER, 1980)

THE CURRENT MODE NUMBER BEING COMPUTED:

MODENO =

ONE OF THE FOLLOWING IS PRINTED FOR EACH TRIAL EIGENVALUE:

FIRST ESTIMATE
SECOND ESTIMATE
SECANT ITERATE
RIGHT BOUND ESTIMATE FROM REFINE
LEFT BOUND ESTIMATE FROM REFINE
RIGHT BOUND ESTIMATE FROM ZEROIN
LEFT BOUND ESTIMATE FROM ZEROIN
BISECTION ESTIMATE

THE TRIAL EIGENVALUE, NUMBER OF ZEROS IN THE TRIAL EIGENFUNCTION, AND INTEGRATION NUMBER:

KN = NZEROS = INTEGRATION NO =

THE FIVE POINTS CENTERED AT THE MATCH POINT FOR EACH UPPER AND LOWER HALF OF TRIAL MODE:

U-UPPER U-LOWER

THE DEPTH DERIVATIVE EVALUATED AT THE MATCH POINT FOR EACH UPPER AND LOWER HALF OF TRIAL MODE:

UPPER DERV = LOWER DERV =

THE DISCONTINUITY IN THE DEPTH DERIVATIVES AT THE MATCH POINT, I.E., DISC = UPPER DERV - LOWER DERV. RATIO IS THE SCALING FACTOR THAT WAS APPLIED TO THE UPPER HALF TO FORCE CONTINUITY IN THE UPPER AND LOWER HALVES OF TRIAL MODE:

DISCONTINUITY = RATIO =

DIAGNOSTIC PRINTS FOR TRACKING DISCONTINUITY (PHI) IN FIRST DERIVATIVE OF TRIAL EIGENFUNCTIONS FOR A RANGE OF TRIAL EIGENVALUES FOR A FIXED MATCH POINT:

PHI ZEROS ZMATCH

ON LTAPE1

NEMESIS GENERATES A DISK/TAPE FILE ON LTAPE1 THAT CONTAINS ALL OF THE RELEVANT INPUT DATA TOGETHER WITH ALL OF THE EIGENVALUES, GROUP VELOCITIES, ATTENUATION TERMS, AND NORMAL MODES. NOTE - WITH THE EXCEPTION OF THE HEADER INFORMATION, ALL QUANTITIES ARE OUTPUT AS FLOATING POINT NUMBERS. LTAPE1 HAS THE FOLLOWING STRUCTURE:

LOGICAL RECORD NO	WORD NO IN RECORD	DESCRIPTION OF RECORD	NO OF WORDS PER RECORD
1	1-8	HEADER INFORMATION	8
2	1	NUMBER OF LAYERS	20
	2	MAXIMUM ALLOWABLE LAYERS	
	3	0.0	
	4	FREQUENCY IN HERTZ	
	5	COMPRESSIONAL SPEED IN SUBSTRATE	
	6	SHEAR SPEED IN SUBSTRATE	
	7	RAYLEIGH SPEED AT SUBSTRATE INTERFACE	
	8	PRESSURE RELEASE SUBSTRATE (1=YES,0=NO)	
	9	LAST MODE COMPUTED	
	10	FIRST MODE COMPUTED	
	11-20	0.0	
3	1-10	INDEX OF THE LAST MESH POINT IN EACH LAYER OF THE MODES, BEGINNING WITH LAYER 1	NU
4	1-10	INDEX OF THE LAST POINT IN EACH LAYER OF THE INPUT SOUND SPEED PROFILE	NU
5	1-10	DEPTH AT EACH LAYER INTERFACE	NU
6	1-10	MESH INCREMENT (IN METERS) FOR EACH LAYER	NU
7	1-10	DENSITY OF EACH LAYER	NU

8	1-N1	DEPTHS CORRESPONDING TO THE INPUT SOUND SPEED PROFILE	N1
9	1-N1	SOUND SPEEDS CORRESPONDING TO THE INPUT SOUND SPEED PROFILE	N1
10 - (N3+9)	1-N2	NORMAL MODES EVALUATED AT EACH MESH POINT (THERE IS ONE RECORD PER MODE)	N2
N3+10	1-N3	EIGENVALUES CORRESPONDING TO EACH MODE	N3
N3+11	1-N3	GROUP VELOCITIES OF EACH MODE	N3
N3+12		ATTENUATION TERMS PER LAYER PER MODE	N4
	1-N5	ATTENUATION TERMS FOR EACH MODE IN EACH LAYER, BEGINNING WITH LAYER 1. BOTH SHEAR AND COMPRESSIONAL ATTENUATIONS ARE COMPUTED. THEREFORE, THERE ARE AS MANY ATTENUATION TERMS FOR EACH MODE AS THERE ARE LAYERS+1	
(N5+1)-2N5		ATTENUATION TERMS FOR SECOND MODE COMPUTED	
(2N5+1)-3N5		ATTENUATION TERMS FOR THIRD MODE COMPUTED	
• • •		• • • • •	
((N3-1)*N5+1) -N3*N5		ATTENUATION TERMS FOR LAST MODE COMPUTED	
END - OF - FILE			

TOTAL NUMBER OF WORDS IN FILE LTAPE1 IS

$$28 + 5*N0 + 2*N1 + (2+N2+N5)*N3$$

DEFINITIONS

N0 MAXIMUM ALLOWABLE LAYERS

N1 TOTAL NO. OF POINTS IN INPUT SOUND SPEED PROFILE. ACCESS WORD NUMBER (LAYERS-1) IN 4TH RECORD

N2 TOTAL NO. OF MESH POINTS IN MODES. ACCESS WORD NUMBER (LAYERS-1) IN 3RD RECORD

N3 TOTAL NO. OF MODES. SUBTRACT FIRST MODE COMPUTED FROM LAST MODE COMPUTED AND ADD 1

N4 N3 * NUMBER OF LAYERS

N5 NUMBER OF LAYERS + 1

REQUIRED RESIDENT ROUTINES

STANDARD FORTRAN

ABS, ALOG10, AMAX1, AMIN1, FLOAT, IABS, IFIX, MAX0, MIN0, MOD, SQRT

NONSTANDARD - THESE MUST BE WRITTEN AT EACH NEW INSTALLATION

EOF (U)

PURPOSE	FUNCTION THAT TESTS FOR AN END OF FILE CONDITION FOLLOWING A READ
FORMAL PARAMETERS	U - UNIT (FILE NAME)
VALUE RETURNED	ZERO IF NO END OF FILE IS ENCOUNTERED NONZERO OTHERWISE

IBUFOUT (U, IFRMAT, ARRAY, NPTS)

PURPOSE	FUNCTION THAT BUFFERS OUT A CONTIGUOUS BLOCK OF WORDS
FORMAL PARAMETERS	U - UNIT (FILE NAME) IFRMAT - ONE FOR BINARY FORMAT ARRAY - ADDRESS OF FIRST WORD IN BLOCK NPTS - NUMBER OF WORDS TO BE BUFFERED OUT
VALUE RETURNED	ZERO IF SUCCESSFUL NONZERO OTHERWISE

CURRENT LIMITS

VARIABLE	DESCRIPTION	LIMIT
MESHMX	MAXIMUM NUMBER OF MESH POINTS	2000
LYRMAX	MAXIMUM NUMBER OF LAYERS	10
MXINPT	MAXIMUM NUMBER OF DEPTH-SOUND SPEED PAIRS WHICH CAN BE INPUT	125
NMODMX	MAXIMUM MODE NUMBER WHICH CAN BE COMPUTED	300

ARRAY DIMENSIONS

ARRAY	ARRAY DIMENSION
AKSQR	MESHMX
DEPTH1	MESHMX
SPEED	MESHMX
U	MESHMX
AKSQRH	LYRMAX
BUFF1	LYRMAX
BUFF2	LYRMAX
BUFF3	LYRMAX
CHALF	LYRMAX
DELZ	LYRMAX
H	LYRMAX
MESH	LYRMAX
NET	LYRMAX
NPTS	LYRMAX
RHO	LYRMAX
ATTEN	LYRMAX+1
Z	MXINPT
C	MXINPT
COEF	MXINPT*3
BUFAKN	NMODMX
BUFGV	NMODMX
BUFATT	NMODMX*(LYRMAX+1)
IHEADR	80 CHARACTERS

COMPUTER RESOURCES

NEMESIS WAS PROGRAMMED ON A CONTROL DATA CORPORATION CYBER 171, UNDER THE NOS 1.3 LEVEL 485 OPERATING SYSTEM. THIS COMPUTER HAS A 60-BIT WORD WITH 10 CHARACTERS PER WORD. THE FORTRAN COMPILER IS FORTRAN FOUR EXTENDED (4.7+485) WHICH IS DESCRIBED IN CDC PUBLICATION 60497800, REVISION D. EFFORTS WERE MADE TO MAINTAIN ANSI STANDARD FORTRAN CODE. PORTIONS OF THE CODE ARE UNAVOIDABLY INSTALLATION DEPENDENT, SUCH AS THE NUMBER OF CHARACTERS PER WORD.

ON THIS MACHINE, THE LAST WORD ADDRESS (LWA) OF NEMESIS WAS 62121 OCTAL WORDS. THIS CAN BE REDUCED BY DECREASING THE SIZES OF THE ARRAYS IN THE MAIN PROGRAM AND APPROPRIATE COMMON BLOCKS, AS DESCRIBED IN THE SECTION, CURRENT LIMITS.

NEMESIS WAS RUN WITH A TYPICAL DEEP WATER PROFILE WITH TWO SEDIMENT LAYERS AND A FLUID SUBSTRATE. EIGENVALUES, EIGENFUNCTIONS, GROUP VELOCITIES, AND ATTENUATION TERMS WERE COMPUTED AND STORED ON A FILE. THE TOTAL EXECUTION TIME FOR THE 140 MODES WITH 1999 MESH POINTS PER MODE WAS 194.15 CP SECONDS (OPTIMIZED). SEE ARL-TM-80-6, CHAPTER 3, FOR FURTHER DETAILS OF THIS EXAMPLE.

III. NEMESIS: EXAMPLES

Two data sets and the corresponding printed output from NEMESIS are included in this chapter. The modeled environment is shown in Fig. 1. It consists of four layers: water, two sediment layers, and the substrate. The density in each of the four layers is 1.0, 1.5, 1.75, and 2.0 g/cm^3, respectively. The sound speeds in the sediment layers vary linearly with depth, and there is a discontinuity in sound speed at the water-sediment interface. Note that the sound speed must be specified at the top and bottom interface of each water and sediment layer, and that within the substrate the shear and compressional speeds must be constant.

The first data set does not include shear waves in the substrate; i.e., the substrate is a fluid, and thus the shear speed is zero. At 50 Hz there are 149 modes, as shown in the printed output. The five attenuation terms listed for each mode pertain to the compressional wave in the water, the sediment layers and the substrate, and the shear wave in the substrate, in that order. Because shear waves are not included, the shear wave attenuation term is identically zero for all modes. In this data set the option to suppress hidden depth calculations is not chosen. Thus, for modes with turning points high above the water-sediment interface (modes 1 to 49), the sediment attenuation terms are zero. Note that the phase velocities of the modes are bounded by the minimum sound speed in the water and the substrate compressional speed. This computation requires 194 cp sec on a Control Data Corporation CYBER 171 when NEMESIS is compiled under maximum optimization.

The second data set describes the environment in Fig. 1 with a solid substrate. The substrate compressional speed is 5000 m/sec and the shear speed is 2700 m/sec. At 50 Hz there are 282 modes with phase velocities bracketed between the minimum sound speed in the water and the shear speed. This computation requires 347 cp sec on the CYBER 171 in the optimized mode.

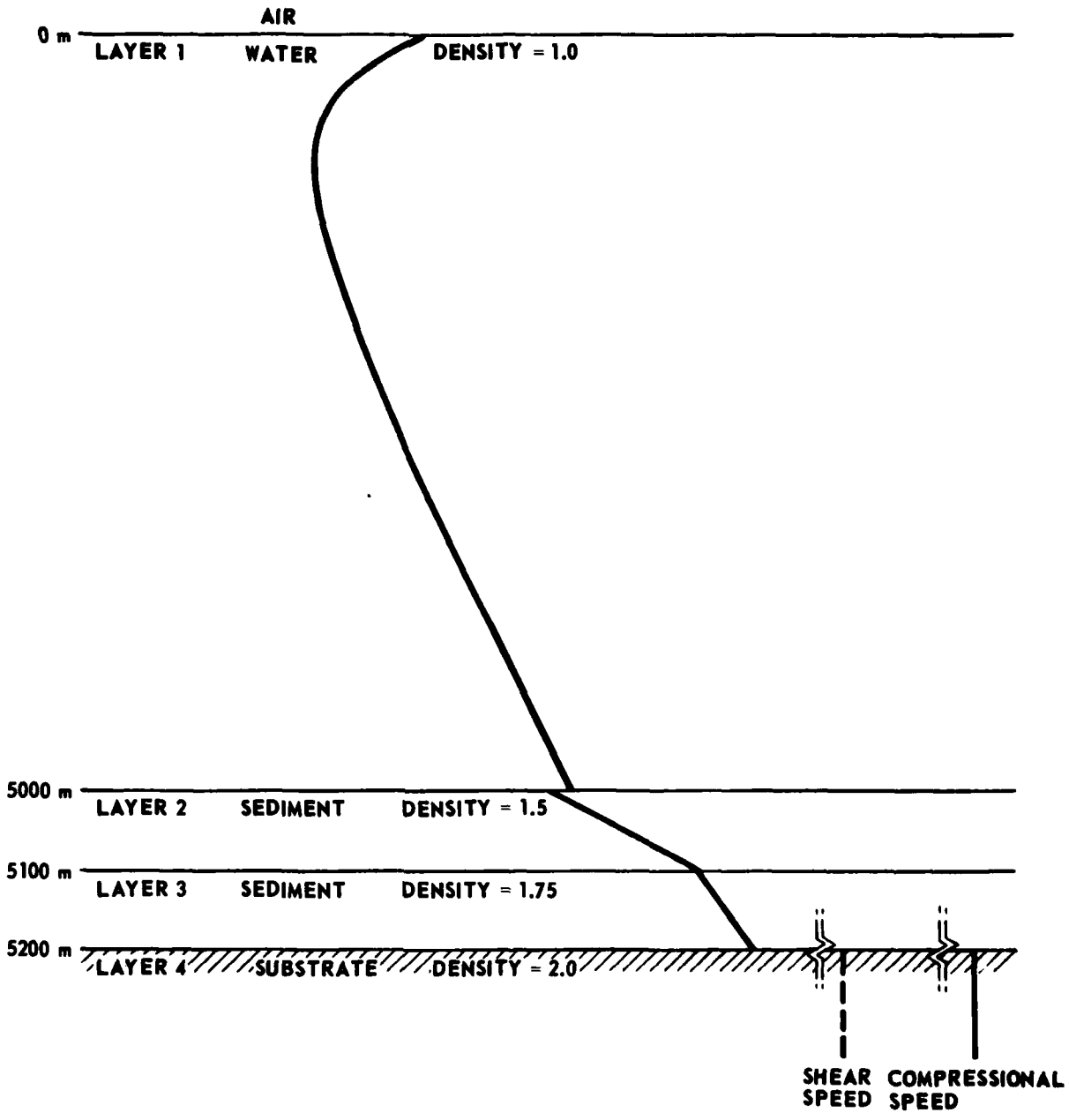


FIGURE 1
A DIAGRAMMATIC REPRESENTATION OF THE ENVIRONMENT DESCRIBED IN THE DATA SETS FOR NEMESIS

ARL:UT
AS-80-1066
SGP-GA
4-15-80

A. DATA SET (1)

The following printout constitutes the data set of the first example generated by the computer model NEMESIS, for this report.

MUNK PROFILE, C1 = 1500, Z1 = 1000, EPS = .0074, B = 1233.33
50.

1.000							
0.000	1527.081	51.000	1523.539	101.000	1520.411	152.000	1517.543
202.000	1515.024	253.000	1512.728	303.000	1510.725	354.000	1508.915
404.000	1507.351	455.000	1505.952	505.000	1504.760	556.000	1503.712
606.000	1502.836	657.000	1502.085	707.000	1501.477	758.000	1500.978
808.000	1500.598	859.000	1500.314	909.000	1500.127	962.000	1500.024
1010.000	1500.001	1061.000	1500.053	1111.000	1500.170	1162.000	1500.352
1212.000	1500.587	1263.000	1500.880	1313.000	1501.216	1364.000	1501.603
1414.000	1502.024	1465.000	1502.492	1515.000	1502.985	1566.000	1503.521
1616.000	1504.076	1667.000	1504.669	1717.000	1505.276	1768.000	1505.919
1818.000	1506.570	1869.000	1507.254	1919.000	1507.943	1970.000	1508.662
2020.000	1509.383	2071.000	1510.133	2121.000	1510.880	2172.000	1511.655
2222.000	1512.426	2273.000	1513.223	2323.000	1514.013	2374.000	1514.828
2424.000	1515.635	2475.000	1516.465	2525.000	1517.296	2576.000	1518.130
2626.000	1518.963	2677.000	1519.818	2727.000	1520.661	2778.000	1521.525
2828.000	1522.377	2879.000	1523.249	2929.000	1524.108	2980.000	1524.988
3030.000	1525.853	3081.000	1526.738	3131.000	1527.606	3182.000	1528.499
3232.000	1529.374	3283.000	1530.268	3333.000	1531.147	3384.000	1532.045
3434.000	1532.926	3485.000	1533.827	3535.000	1534.712	3586.000	1535.616
3636.000	1536.503	3687.000	1537.408	3737.000	1538.297	3788.000	1539.205
3838.000	1540.095	3889.000	1541.005	3939.000	1541.897	3990.000	1542.807
4040.000	1543.700	4091.000	1544.612	4141.000	1545.506	4192.000	1546.419
4242.000	1547.314	4293.000	1548.227	4343.000	1549.123	4394.000	1550.037
4444.000	1552.934	4495.000	1551.849	4545.000	1552.746	4596.000	1553.661
4646.000	1554.558	5000.000	1560.917				
1.500							
5000.000	1550.000	5100.000	1650.000				
1.750							
5100.000	1650.000	5200.000	1680.000				
2.000							
5200.000	1700.000						

B. PRINTED OUTPUT (1)

The following printout is the output generated by data set (1) of NEMESIS.

NEMESIS ARL-UT NORMAL MODE MODEL
VERSION 1.2

MUNK PROFILE, C1 = 1500, Z1 = 1000, EPS = .0074, B = 1233.33

FREQUENCY (HZ)	50.000
NUMBER OF EXISTING MODES	149
FIRST MODE COMPUTED	1
LAST MODE COMPUTED	149
DEPTH (M) AT WHICH MODES ARE MATCHED	1010.000

NO OPTIONS SELECTED

GEOACOUSTIC PROFILE

LAYER	TOTAL DEPTH (M)	LOCAL DEPTH (M)	COMPRESSIONAL WAVE SPEED (M/SEC)	SHEAR WAVE SPEED (M/SEC)	RAYLEIGH WAVE SPEED (M/SEC)	DENSITY (G/CC)	SAMPLING POINTS
1	0.000	0.000	1527.681			1.000	1921
	51.000	51.000	1523.539				
	101.000	101.000	1520.411				
	152.000	152.000	1517.543				
	202.000	202.000	1515.024				
	253.000	253.000	1512.728				
	303.000	303.000	1510.725				
	354.000	354.000	1508.915				
	404.000	404.000	1507.351				
	455.000	455.000	1505.952				
	505.000	505.000	1504.760				
	556.000	556.000	1503.712				
	606.000	606.000	1502.836				
	657.000	657.000	1502.085				
	707.000	707.000	1501.477				
	758.000	758.000	1500.978				
	808.000	808.000	1500.598				
	859.000	859.000	1500.314				
	909.000	909.000	1500.127				
	960.000	960.000	1500.024				
	1010.000	1010.000	1500.001				
	1061.000	1061.000	1500.053				
	1111.000	1111.000	1500.170				
	1162.000	1162.000	1500.352				
	1212.000	1212.000	1500.587				
	1263.000	1263.000	1500.860				
	1313.000	1313.000	1501.216				
	1364.000	1364.000	1501.603				
	1414.000	1414.000	1502.024				
	1465.000	1465.000	1502.492				
	1515.000	1515.000	1502.985				
	1566.000	1566.000	1503.521				
	1616.000	1616.000	1504.076				
	1667.000	1667.000	1504.669				
	1717.000	1717.000	1505.276				
	1768.000	1768.000	1505.919				
	1818.000	1818.000	1506.570				
	1869.000	1869.000	1507.254				
	1919.000	1919.000	1507.943				
	1970.000	1970.000	1508.662				
	2020.000	2020.000	1509.383				
	2071.000	2071.000	1510.133				
	2121.000	2121.000	1510.880				
	2172.000	2172.000	1511.655				
	2222.000	2222.000	1512.426				
	2273.000	2273.000	1513.223				
	2323.000	2323.000	1514.013				

	2374.000	2374.000	1514.828				
	2424.000	2424.000	1515.635				
	2475.000	2475.000	1516.465				
	2525.000	2525.000	1517.286				
	2576.000	2576.000	1518.130				
	2626.000	2626.000	1518.963				
	2677.000	2677.000	1519.818				
	2727.000	2727.000	1520.661				
	2778.000	2778.000	1521.525				
	2828.000	2828.000	1522.377				
	2879.000	2879.000	1523.249				
	2929.000	2929.000	1524.108				
	2980.000	2980.000	1524.988				
	3030.000	3030.000	1525.853				
	3081.000	3081.000	1526.738				
	3131.000	3131.000	1527.608				
	3182.000	3182.000	1528.499				
	3232.000	3232.000	1529.374				
	3283.000	3283.000	1530.268				
	3333.000	3333.000	1531.147				
	3384.000	3384.000	1532.045				
	3434.000	3434.000	1532.926				
	3485.000	3485.000	1533.827				
	3535.000	3535.000	1534.712				
	3586.000	3586.000	1535.616				
	3636.000	3636.000	1536.503				
	3687.000	3687.000	1537.408				
	3737.000	3737.000	1538.297				
	3788.000	3788.000	1539.205				
	3838.000	3838.000	1540.095				
	3889.000	3889.000	1541.005				
	3939.000	3939.000	1541.897				
	3990.000	3990.000	1542.807				
	4040.000	4040.000	1543.700				
	4091.000	4091.000	1544.612				
	4141.000	4141.000	1545.506				
	4192.000	4192.000	1546.419				
	4242.000	4242.000	1547.314				
	4293.000	4293.000	1548.227				
	4343.000	4343.000	1549.123				
	4394.000	4394.000	1550.037				
	4444.000	4444.000	1550.934				
	4495.000	4495.000	1551.849				
	4545.000	4545.000	1552.746				
	4596.000	4596.000	1553.661				
	4646.000	4646.000	1554.558				
	5000.000	5000.000	1560.917				
2	5000.000	0.000	1550.000			1.500	39
	5100.000	100.000	1650.000				
3	5100.000	0.000	1650.000			1.752	36
	5200.000	100.000	1680.000				
4	5200.000	0.000	1700.000	0.000	2.000	2.000	

MODE CHARACTERISTICS

MODE NUMBER	WAVE NUMBER (1/M)	PHASE VELOCITY (M/SEC)	GROUP VELOCITY (M/SEC)	ATTENUATION TERMS
1	.209369849	1500.4991	1500.0009	.100016603E+01 0. 0. 0. 0.
2	.209231409	1501.4919	1500.0084	.100049429E+01 0. 0. 0. 0.
3	.209094015	1502.4785	1500.0227	.100081806E+01 0. 0. 0. 0.
4	.208957603	1503.4594	1500.0443	.100113733E+01 0. 0. 0. 0.
5	.208822191	1504.4343	1500.0725	.100145223E+01 0. 0. 0. 0.
6	.208687766	1505.4034	1500.1074	.100176282E+01 0. 0. 0. 0.
7	.208554294	1506.3668	1500.1480	.100206944E+01 0. 0. 0. 0.

8	.208421764	1507.3247	1500.1949	.100237195E+01 0. 0. 0. 0.
9	.208290160	1508.2770	1500.2476	.100267054E+01 0. 0. 0. 0.
10	.208159474	1509.2240	1500.3062	.100296520E+01 0. 0. 0. 0.
11	.208029680	1510.1656	1500.3690	.100325653E+01 0. 0. 0. 0.
12	.207900757	1511.1021	1500.4385	.100354376E+01 0. 0. 0. 0.
13	.207772716	1512.0333	1500.5118	.100382785E+01 0. 0. 0. 0.
14	.207645512	1512.9596	1500.5901	.100410843E+01 0. 0. 0. 0.
15	.207519141	1513.8809	1500.6715	.100438618E+01 0. 0. 0. 0.
16	.207393575	1514.7975	1500.7568	.100466094E+01 0. 0.

				0. 0.
17	.207268802	1515.7094	1500.6467	.100493244E+01 0. 0. 0. 0.
18	.207144803	1516.6167	1500.9353	.100520271E+01 0. 0. 0. 0.
19	.207021525	1517.5198	1501.0229	.100547180E+01 0. 0. 0. 0.
20	.206898936	1518.4190	1501.1075	.100574042E+01 0. 0. 0. 0.
21	.206776963	1519.3146	1501.1826	.100601097E+01 0. 0. 0. 0.
22	.206655527	1520.2074	1501.2477	.100628377E+01 0. 0. 0. 0.
23	.206534551	1521.0979	1501.2999	.100655999E+01 0. 0. 0. 0.
24	.206413938	1521.9867	1501.3375	.100684046E+01 0. 0. 0. 0.

25	.206293595	1522.8745	1501.3599	.100712556E+01 0. 0. 0. 0.
26	.206173442	1523.7620	1501.3723	.100741376E+01 0. 0. 0. 0.
27	.206053429	1524.6495	1501.3780	.100770413E+01 0. 0. 0. 0.
28	.205933512	1525.5374	1501.3803	.100799561E+01 0. 0. 0. 0.
29	.205813688	1526.4255	1501.3862	.100828584E+01 0. 0. 0. 0.
30	.205693961	1527.3140	1501.3962	.100857465E+01 0. 0. 0. 0.
31	.205574351	1528.2026	1501.4155	.100886027E+01 0. 0. 0. 0.
32	.205454890	1529.0912	1501.4422	.100914324E+01 0. 0. 0. 0.
33	.205335596	1529.9796	1501.4777	.100942306E+01 0. 0. 0.

				0.
34	.205216505	1530.8674	1501.5261	.100969821E+01 0. 0. 0. 0.
35	.205097665	1531.7545	1501.5867	.100996882E+01 0. 0. 0. 0.
36	.204979097	1532.6405	1501.6534	.101023695E+01 0. 0. 0. 0.
37	.204860823	1533.5254	1501.7309	.101050089E+01 0. 0. 0. 0.
38	.204742872	1534.4088	1501.8176	.101076114E+01 0. 0. 0. 0.
39	.204625265	1535.2907	1501.9117	.101101821E+01 0. 0. 0. 0.
40	.204508017	1536.1709	1502.0126	.101127232E+01 0. 0. 0. 0.
41	.204391138	1537.0493	1502.1210	.101152320E+01 0. 0. 0. 0.
42	.204274661	1537.9258	1502.2427	.101176877E+01

				0. 0. 0. 0.
43	.20415859E	1538.8801	1502.3649	.101201335E+01 0. 0. 0. 0.
44	.204042940	1539.6723	1502.4916	.101225560E+01 0. 0. 0. 0.
45	.203927701	1540.5424	1502.6258	.101249448E+01 0. 0. 0. 0.
46	.203812890	1541.4102	1502.7650	.101273078E+01 0. 0. 0. 0.
47	.203698514	1542.2757	1502.9104	.101296410E+01 0. 0. 0. 0.
48	.203584580	1543.1388	1503.0596	.101319525E+01 0. 0. 0. 0.
49	.203471085	1543.9996	1503.2120	.101342436E+01 0. 0. 0. 0.
50	.203358035	1544.8579	1503.3699	.101365072E+01 .6711712771-18 0. 0. 0.

51	.203245433	1545.7138	1503.5302	.121387535E+01 .176313358E-16 0. 0. 0.
52	.203133270	1546.5673	1503.6904	.101409908E+01 .278639986E-15 0. 0. 0.
53	.203021547	1547.4183	1503.8591	.101431903E+01 .385942629E-14 .141868622E-19 0. 0.
54	.202910280	1548.2669	1504.0322	.101453655E+01 .486510197E-13 .372887306E-18 0. 0.
55	.202799455	1549.1130	1504.2025	.101475409E+01 .559769306E-12 .628755545E-17 0. 0.
56	.202689068	1549.9566	1504.3776	.101496905E+01 .586951695E-11 .733597534E-16 0. 0.
57	.202579124	1550.7978	1504.5567	.101518177E+01 .559617182E-10 .756813134E-15 .209550546E-21 0.
58	.202469616	1551.6366	1504.7334	.101539438E+01 .463921345E-09 .704488793E-14 .206701293E-20 0.
59	.202360538	1552.4730	1504.9159	.101560408E+01 .378664237E-08

				.5634458701E-13 .1845300281E-19 0.
60	.202251899	1553.3060	1505.1027	.1015811411E+01 .2671648281E-07 .4507700911E-12 .1484908931E-18 0.
61	.202143694	1554.1383	1505.2897	.1016017661E+01 .1692461881E-06 .3074457251E-11 .1073046961E-17 0.
62	.202035919	1554.9674	1505.4796	.1016221331E+01 .9560424551E-06 .1873839931E-10 .6928957691E-17 0.
63	.201928572	1555.7940	1505.6708	.1016420631E+01 .4815709191E-05 .1014223711E-09 .3973142861E-16 0.
64	.201821650	1556.6183	1505.8630	.1016606031E+01 .2132295641E-04 .4835852141E-09 .2006870311E-15 0.
65	.201715140	1557.4402	1506.0469	.1016748951E+01 .8224083201E-04 .2008611461E-08 .8830221731E-15 0.
66	.201608995	1558.2602	1506.1913	.1016775701E+01 .2719492181E-03 .7153591901E-08 .3331376461E-14 0.
67	.201503035	1559.0796	1506.1797	.1016562321E+01 .7543620001E-03 .2137689981E-07 .1054643281E-13 0.

68	.201396738	1559.9024	1505.7987	.121599440E+01 .171755595E-02 .524645842E-07 .2743153888E-13 0.
69	.201289147	1560.7362	1504.8423	.101512304E+01 .318312431E-02 .104944714E-06 .582048921E-13 0.
70	.201179063	1561.5903	1503.2999	.101421979E+01 .488695358E-02 .174276191E-06 .102691550E-12 0.
71	.201065535	1562.4720	1501.4005	.101356461E+01 .647468536E-02 .250474437E-06 .157136109E-12 0.
72	.200948140	1563.3848	1499.3953	.101326804E+01 .775188068E-02 .326363337E-06 .218504470E-12 0.
73	.200826855	1564.3290	1497.4303	.101329289E+01 .870599480E-02 .400218382E-06 .266648816E-12 0.
74	.200701852	1565.3033	1495.5573	.101355180E+01 .940603381E-02 .473667596E-06 .363780368E-12 0.
75	.200573347	1566.3061	1493.7778	.101396704E+01 .992648771E-02 .549412534E-06 .453476843E-12 0.
76	.200441542	1567.3361	1492.0796	.101448118E+01 .103342803E-01 .630322586E-06

				.560340157E-12
				0.
77	.200306609	1568.3919	1490.4454	.101505747E+01
				.106654846E-01
				.719147400E-06
				.690002976E-12
				0.
78	.200168687	1569.4726	1488.8615	.101567135E+01
				.109510129E-01
				.818676730E-06
				.849532026E-12
				0.
79	.200027889	1570.5773	1487.3167	.101630635E+01
				.112108071E-01
				.931898270E-06
				.104795962E-11
				0.
80	.199884311	1571.7055	1485.8021	.101695138E+01
				.114587572E-01
				.106215577E-05
				.129699095E-11
				0.
81	.199738030	1572.8565	1484.3112	.101759850E+01
				.117049021E-01
				.121333649E-05
				.161198206E-11
				0.
82	.199589112	1574.0301	1482.8381	.101824223E+01
				.119565492E-01
				.139004233E-05
				.201322178E-11
				0.
83	.199437612	1575.2258	1481.3786	.101887781E+01
				.122197619E-01
				.159788461E-05
				.252783102E-11
				0.
84	.199283579	1576.4433	1479.9301	.101950065E+01
				.124999636E-01
				.184379106E-05
				.319234375E-11
				0.

85	.199127057	1577.6825	1478.4895	.122010725E+01 .128015681E-01 .213626972E-05 .425610697E-11 0.
86	.198968081	1578.9430	1477.0548	.122069410E+01 .131287690E-01 .248593045E-05 .518636955E-11 0.
87	.198806687	1580.2248	1475.6246	.122125697E+01 .134861790E-01 .290615464E-05 .667555373E-11 0.
88	.198642905	1581.5277	1474.1975	.122179162E+01 .138762471E-01 .341379251E-05 .865129359E-11 0.
89	.198476764	1582.8516	1472.7729	.122229369E+01 .143122515E-01 .403029532E-05 .112913784E-10 0.
90	.198308291	1584.1963	1471.3504	.122275732E+01 .147870011E-01 .473322029E-05 .146449865E-10 0.
91	.198137513	1585.5618	1469.9297	.122317659E+01 .153151956E-01 .570710999E-05 .196641127E-10 0.
92	.197964456	1586.9478	1468.5108	.122354448E+01 .159015238E-01 .684793064E-05 .262496315E-10 0.
93	.197789147	1588.3544	1467.0943	.122385295E+01 .165537900E-01 .826433975E-05 .353196297E-10

				0.
94	.197611612	1589.7814	1465.6809	.102409272E+01 .172808671E-01 .100330778E-04 .479113463E-10 0.
95	.197431879	1591.2287	1464.2717	.102425326E+01 .180927589E-01 .122546127E-04 .655339470E-10 0.
96	.197249979	1592.6961	1462.8680	.102432265E+01 .192066676E-01 .150609738E-04 .903989264E-10 0.
97	.197065945	1594.1834	1461.4717	.102428764E+01 .200169497E-01 .166261482E-04 .125768782E-09 0.
98	.196879813	1595.6906	1460.0851	.102413383E+01 .211548716E-01 .231797206E-04 .176485022E-09 0.
99	.196691623	1597.2173	1458.7107	.102384623E+01 .224280907E-01 .290244937E-04 .249769866E-09 0.
100	.196501418	1598.7634	1457.3514	.102341021E+01 .238496472E-01 .365585745E-04 .356435424E-09 0.
101	.196309248	1600.3284	1456.0104	.102281333E+01 .254302137E-01 .463017646E-04 .512696418E-09 0.
102	.196115166	1601.9121	1454.6905	.102204820E+01

				.271752645E-01 .589245566E-04 .742847016E-09 0.
103	.195919230	1603.5142	1453.3940	.102111696E+01 .290808038E-01 .752750798E-04 .108312384E-06 0.
104	.195721497	1605.1342	1452.1216	.102003759E+01 .311274037E-01 .963643995E-04 .158708820E-08 0.
105	.195522024	1606.7718	1450.8713	.101885172E+01 .332727117E-01 .123503578E-03 .233274173E-08 0.
106	.195320859	1608.4266	1449.6372	.101763329E+01 .354435630E-01 .157938989E-03 .343123654E-08 0.
107	.195118033	1610.0986	1448.4073	.101649478E+01 .375324533E-01 .201011393E-03 .503639919E-08 0.
108	.194913548	1611.7877	1447.1634	.101558631E+01 .393889947E-01 .253762155E-03 .735355621E-08 0.
109	.194707370	1613.4945	1445.8814	.101508193E+01 .408537414E-01 .316777566E-03 .106460663E-07 0.
110	.194499417	1615.2196	1444.5342	.101515001E+01 .417666843E-01 .389783711E-03 .152397665E-07 0.

111	.194289566	1616.9642	1443.0975	.101591181E+01 .422162843E-01 .471624596E-03 .215303092E-07 0.
112	.194077657	1618.7297	1441.5553	.101740384E+01 .415786753E-01 .561364573E-03 .300044148E-07 0.
113	.193863519	1620.5177	1439.9050	.101956033E+01 .405177159E-01 .657103189E-03 .412914595E-07 0.
114	.193646991	1622.3297	1438.1573	.102222731E+01 .389664482E-01 .758480712E-03 .562615725E-07 0.
115	.193427945	1624.1669	1436.3331	.102520068E+01 .371808991E-01 .866361952E-03 .761666230E-07 0.
116	.193206292	1626.0302	1434.4581	.102827027E+01 .352994149E-01 .983352171E-03 .102987011E-06 0.
117	.192981992	1627.9201	1432.5580	.103125255E+01 .335116323E-01 .111394911E-02 .139610394E-06 0.
118	.192755046	1629.8366	1430.6549	.103400537E+01 .319448219E-01 .126467916E-02 .190630900E-06 0.
119	.192525488	1631.7801	1428.7671	.103642609E+01 .306956724E-01

				.144444708E-02 .263238251E-06 0.
120	.192293378	1633.7498	1426.9096	.103844083E+01 .297901160E-01 .166525970E-02 .368916656E-06 0.
121	.192058799	1635.7452	1425.0957	.103998996E+01 .292959499E-01 .1943527351-02 .526369800E-06 0.
122	.191821854	1637.7658	1423.3391	.104101325E+01 .292347568E-01 .230219925E-02 .766731775E-06 0.
123	.191582665	1639.8105	1421.6559	.104143567E+01 .296418766E-01 .277414720E-02 .114305629E-05 0.
124	.191341384	1641.8783	1420.0675	.104115321E+01 .305642091E-01 .342747070E-02 .174796701E-05 0.
125	.191098197	1643.9677	1418.6031	.104001832E+01 .320653672E-01 .427371011E-02 .274710595E-05 0.
126	.192853340	1646.0769	1417.3035	.103782595E+01 .342258759E-01 .548019371E-02 .444331929E-05 0.
127	.190607119	1648.2032	1416.2237	.103430621E+01 .371319122E-01 .718722930E-02 .739990724E-05 0.

128	.190359924	1650.3435	1415.4323	.102914431E+01 .408362012E-01 .962723700E-02 .126716174E-04 0.
129	.190112243	1652.4936	1414.9993	.102207767E+01 .452596243E-01 .131105546E-01 .222064472E-04 0.
130	.189864627	1654.6487	1414.9534	.101316496E+01 .499922372E-01 .179715961E-01 .394218882E-04 0.
131	.189617555	1656.8047	1415.1902	.100330292E+01 .540152024E-01 .243666013E-01 .696485534E-04 0.
132	.189371150	1658.9605	1415.3592	.994737137E+00 .556263524E-01 .316829492E-01 .119499024E-03 0.
133	.189124817	1661.1213	1414.8984	.990587780E+00 .531682879E-01 .392754358E-01 .194408188E-03 0.
134	.188877208	1663.2990	1413.3935	.992664990E+00 .465220804E-01 .450208402E-01 .296928460E-03 0.
135	.188626794	1665.5071	1410.9755	.999527706E+00 .376377537E-01 .485556247E-01 .431365307E-03 0.
136	.188372670	1667.7540	1408.2369	.100745887E+01 .291119963E-01 .537598644E-01

				.614601423E-03 0.
137	.188114901	1670.0392	1405.8333	.101284031E+01 .2261149271-01 .532791574E-01 .690223531E-03 0.
138	.187854397	1672.3551	1404.3049	.101298574E+01 .187676860E-01 .578580122E-01 .134679542E-02 0.
139	.187592781	1674.6674	1404.1781	.100544599E+01 .178844815E-01 .662458988E-01 .216131485E-02 0.
140	.187332432	1677.0148	1406.0389	.987592312E+00 .205368942E-01 .799318166E-01 .365567006E-02 0.
141	.187076297	1679.3109	1409.9170	.959827914E+00 .272574054E-01 .975858112E-01 .620986707E-02 0.
142	.186825894	1681.5617	1413.1647	.935928275E+00 .358656069E-01 .108970632E+00 .951802569E-02 0.
143	.186577179	1683.8033	1410.8728	.940461261E+00 .397409601E-01 .996773152E-01 .118257902E-01 0.
144	.186321993	1686.1094	1403.2262	.971421986E+00 .362231702E-01 .759356486E-01 .121149745E-01 0.

145	.186056328	1688.5170	1395.2417	.100356988E+01 .321033505E-01 .543623155E-01 .116541078E-01 0.
146	.185781564	1691.0142	1389.3654	.102466736E+01 .251653453E-01 .411578844E-01 .118697739E-01 0.
147	.185500676	1693.5748	1385.7072	.103443650E+01 .221596655E-01 .348244351E-01 .137686973E-01 0.
148	.185216616	1696.1721	1384.4528	.103257264E+01 .209765405E-01 .335194957E-01 .195480018E-01 0.
149	.184933832	1698.7658	1389.4109	.100392247E+01 .211051277E-01 .369247473E-01 .433024147E-01 0.

C. DATA SET (2)

The following printout constitutes the data set for the second example generated by NEMESIS.

MEAN PROFILE, C1 = 1500, Z1 = 1000, EPS = .0074, B = 1233.33
50.

1.000							
0.000	1527.081	51.000	1523.539	101.000	1520.411	152.000	1517.543
202.000	1515.024	253.000	1512.728	303.000	1510.725	354.000	1508.915
404.000	1507.351	455.000	1505.952	505.000	1504.760	556.000	1503.712
606.000	1502.836	657.000	1502.085	707.000	1501.477	758.000	1500.978
808.000	1500.596	859.000	1500.314	909.000	1500.127	960.000	1500.024
1010.000	1500.001	1061.000	1500.053	1111.000	1500.170	1162.000	1500.352
1212.000	1500.587	1263.000	1500.880	1313.000	1501.216	1364.000	1501.623
1414.000	1502.024	1465.000	1502.492	1515.000	1502.985	1566.000	1503.521
1616.000	1504.076	1667.000	1504.669	1717.000	1505.276	1768.000	1505.919
1818.000	1506.570	1869.000	1507.254	1919.000	1507.943	1970.000	1508.662
2020.000	1509.383	2071.000	1510.133	2121.000	1510.880	2172.000	1511.655
2222.000	1512.426	2273.000	1513.223	2323.000	1514.013	2374.000	1514.828
2424.000	1515.635	2475.000	1516.465	2525.000	1517.286	2576.000	1518.130
2626.000	1518.963	2677.000	1519.816	2727.000	1520.651	2778.000	1521.525
2828.000	1522.377	2879.000	1523.249	2929.000	1524.108	2980.000	1524.986
3030.000	1525.853	3081.000	1526.738	3131.000	1527.608	3182.000	1528.499
3232.000	1529.374	3283.000	1530.268	3333.000	1531.147	3384.000	1532.045
3434.000	1532.926	3485.000	1533.827	3535.000	1534.712	3586.000	1535.616
3636.000	1536.503	3687.000	1537.408	3737.000	1538.297	3788.000	1539.205
3838.000	1540.095	3889.000	1541.005	3939.000	1541.897	3990.000	1542.807
4040.000	1543.700	4091.000	1544.612	4141.000	1545.506	4192.000	1546.419
4242.000	1547.314	4293.000	1548.227	4343.000	1549.123	4394.000	1550.037
4444.000	1550.934	4495.000	1551.849	4545.000	1552.746	4596.000	1553.661
4646.000	1554.558	5000.000	1560.917				
1.500							
5000.000	1550.000	5100.000	1650.000				
1.750							
5100.000	1650.000	5200.000	1680.000				
2.000							
5200.000	5000.000	5200.000	2700.000				

D. PRINTED OUTPUT (2)

The following printout is the output of data set (2) from NEMESIS.

NEMESIS ARL-UT NORMAL MODE MODEL
VERSION 1.2

MUNK PROFILE, C1 = 1500, Z1 = 1000, EPS = .0074, B = 1233.33

FREQUENCY (HZ)	50.000
NUMBER OF EXISTING MODES	282
FIRST MODE COMPUTED	1
LAST MODE COMPUTED	282
DEPTH (M) AT WHICH MODES ARE MATCHED	1010.000

NO OPTIONS SELECTED

GEOACOUSTIC PROFILE

LAYER	TOTAL DEPTH (M)	LOCAL DEPTH (M)	COMPRESSIONAL WAVE SPEED (M/SEC)	SHEAR WAVE SPEED (M/SEC)	RAYLEIGH WAVE SPEED (M/SEC)	DENSITY (G/CC)	SAMPLING POINTS
1	0.000	0.000	1527.061			1.030	1921
	51.000	51.000	1523.539				
	101.000	101.000	1520.411				
	152.000	152.000	1517.543				
	202.000	202.000	1515.024				
	253.000	253.000	1512.728				
	303.000	303.000	1510.725				
	354.000	354.000	1508.915				
	404.000	404.000	1507.351				
	455.000	455.000	1505.952				
	505.000	505.000	1504.760				
	556.000	556.000	1503.712				
	606.000	606.000	1502.836				
	657.000	657.000	1502.085				
	707.000	707.000	1501.477				
	758.000	758.000	1500.978				
	808.000	808.000	1500.598				
	859.000	859.000	1500.314				
	909.000	909.000	1500.127				
	960.000	960.000	1500.024				
	1010.000	1010.000	1500.001				
	1061.000	1061.000	1500.053				
	1111.000	1111.000	1500.170				
	1162.000	1162.000	1500.352				
	1212.000	1212.000	1500.587				
	1263.000	1263.000	1500.880				
	1313.000	1313.000	1501.216				
	1364.000	1364.000	1501.603				
	1414.000	1414.000	1502.024				
	1465.000	1465.000	1502.492				
	1515.000	1515.000	1502.985				
	1566.000	1566.000	1503.521				
	1616.000	1616.000	1504.076				
	1667.000	1667.000	1504.669				
	1717.000	1717.000	1505.276				
	1768.000	1768.000	1505.919				
	1818.000	1818.000	1506.570				
	1869.000	1869.000	1507.254				
	1919.000	1919.000	1507.943				
	1970.000	1970.000	1508.662				
	2020.000	2020.000	1509.383				
	2071.000	2071.000	1510.133				
	2121.000	2121.000	1510.880				
	2172.000	2172.000	1511.655				
	2222.000	2222.000	1512.426				
	2273.000	2273.000	1513.223				
	2323.000	2323.000	1514.013				

	2374.000	2374.000	1514.828				
	2424.000	2424.000	1515.635				
	2475.000	2475.000	1516.465				
	2525.000	2525.000	1517.286				
	2576.000	2576.000	1518.130				
	2626.000	2626.000	1518.963				
	2677.000	2677.000	1519.818				
	2727.000	2727.000	1520.661				
	2778.000	2778.000	1521.525				
	2828.000	2828.000	1522.377				
	2879.000	2879.000	1523.249				
	2929.000	2929.000	1524.108				
	2980.000	2980.000	1524.988				
	3030.000	3030.000	1525.853				
	3081.000	3081.000	1526.738				
	3131.000	3131.000	1527.608				
	3182.000	3182.000	1528.499				
	3232.000	3232.000	1529.374				
	3283.000	3283.000	1530.268				
	3333.000	3333.000	1531.147				
	3384.000	3384.000	1532.045				
	3434.000	3434.000	1532.926				
	3485.000	3485.000	1533.827				
	3535.000	3535.000	1534.712				
	3586.000	3586.000	1535.616				
	3636.000	3636.000	1536.503				
	3687.000	3687.000	1537.408				
	3737.000	3737.000	1538.297				
	3788.000	3788.000	1539.205				
	3838.000	3838.000	1540.095				
	3889.000	3889.000	1541.005				
	3939.000	3939.000	1541.897				
	3990.000	3990.000	1542.807				
	4040.000	4040.000	1543.700				
	4091.000	4091.000	1544.612				
	4141.000	4141.000	1545.506				
	4192.000	4192.000	1546.419				
	4242.000	4242.000	1547.314				
	4293.000	4293.000	1548.227				
	4343.000	4343.000	1549.123				
	4394.000	4394.000	1550.037				
	4444.000	4444.000	1550.934				
	4495.000	4495.000	1551.849				
	4545.000	4545.000	1552.746				
	4596.000	4596.000	1553.661				
	4646.000	4646.000	1554.558				
	5000.000	5000.000	1560.917				
2	5000.000	0.000	1550.000			1.500	39
	5100.000	100.000	1650.000				
3	5100.000	0.000	1650.000			1.750	39
	5200.000	100.000	1680.000				
4	5200.000	0.000	5000.000	2700.000	2501.555	2.000	

MODE CHARACTERISTICS

MODE NUMBER	WAVE NUMBER (1/M)	PHASE VELOCITY (M/SEC)	GROUP VELOCITY (M/SEC)	ATTENUATION TERMS
1	.209369849	1500.4991	1500.0009	.100c166031+01 0. 0. 0. 0.
2	.209231409	1501.4919	1500.0084	.100049429E+01 0. 0. 0. 0.
3	.209094015	1502.4785	1500.0227	.100081806E+01 0. 0. 0. 0.
4	.208957603	1503.4594	1500.0443	.100113733E+01 0. 0. 0. 0.
5	.208822191	1504.4343	1500.0725	.100145223E+01 0. 0. 0. 0.
6	.208687766	1505.4034	1500.1074	.100176282E+01 0. 0. 0. 0.
7	.208554294	1506.3668	1500.1480	.100206944E+01 0. 0. 0. 0.

8	.208421764	1507.3247	1500.1949	.100237195E+01 0. 0. 0. 0.
9	.208290160	1508.2770	1500.2476	.100267054E+01 0. 0. 0. 0.
10	.208159474	1509.2240	1500.3062	.100296520E+01 0. 0. 0. 0.
11	.208029680	1510.1656	1500.3690	.100325653E+01 0. 0. 0. 0.
12	.207900757	1511.1021	1500.4385	.100354378E+01 0. 0. 0. 0.
13	.207772716	1512.0333	1500.5118	.100382785E+01 0. 0. 0. 0.
14	.207645512	1512.9596	1500.5901	.100410843E+01 0. 0. 0. 0.
15	.207519141	1513.8809	1500.6715	.100438618E+01 0. 0. 0. 0.
16	.207393575	1514.7975	1500.7568	.100466094E+01 0. 0.

				0. 0.
17	.207268802	1515.7094	1500.8467	.100493244E+01 0. 0. 0. 0.
18	.207144803	1516.6167	1500.9353	.100520271E+01 0. 0. 0. 0.
19	.207021525	1517.5198	1501.0229	.100547190E+01 0. 0. 0. 0.
20	.206898936	1518.4190	1501.1075	.100574042E+01 0. 0. 0. 0.
21	.206776963	1519.3146	1501.1926	.100601097E+01 0. 0. 0. 0.
22	.206655527	1520.2074	1501.2477	.100628377E+01 0. 0. 0. 0.
23	.206534551	1521.0979	1501.2999	.100655999E+01 0. 0. 0. 0.
24	.206413938	1521.9867	1501.3375	.100684046E+01 0. 0. 0. 0.

25	.206293595	1522.8745	1501.3599	.100712556E+01 0. 0. 0. 0.
26	.206173442	1523.7620	1501.3723	.100741378E+01 0. 0. 0. 0.
27	.206053429	1524.6495	1501.3780	.100770413E+01 0. 0. 0. 0.
28	.205933512	1525.5374	1501.3803	.100799561E+01 0. 0. 0. 0.
29	.205813688	1526.4255	1501.3862	.100828564E+01 0. 0. 0. 0.
30	.205693961	1527.3140	1501.3962	.100857465E+01 0. 0. 0. 0.
31	.205574351	1528.2026	1501.4155	.100886027E+01 0. 0. 0. 0.
32	.205454890	1529.0912	1501.4422	.100914324E+01 0. 0. 0. 0.
33	.205335596	1529.9796	1501.4777	.100942306E+01 0. 0. 0.

				0.
34	.205216505	1530.8674	1501.5261	.100969821E+01 0. 0. 0. 0.
35	.205097665	1531.7545	1501.5867	.100968821E+01 0. 0. 0. 0.
36	.204979097	1532.6405	1501.6534	.101023695E+01 0. 0. 0. 0.
37	.204860823	1533.5254	1501.7309	.101050089E+01 0. 0. 0. 0.
38	.204742872	1534.4088	1501.8176	.101076114E+01 0. 0. 0. 0.
39	.204625265	1535.2907	1501.9117	.101101821E+01 0. 0. 0. 0.
40	.204508017	1536.1709	1502.0126	.101127232E+01 0. 0. 0. 0.
41	.204391138	1537.0493	1502.1210	.101152320E+01 0. 0. 0. 0.
42	.204274661	1537.9258	1502.2427	.101176877E+01

				0. 0. 0. 0.
43	.204158598	1538.6001	1502.3649	.1012013356-01 0. 0. 0. 0.
44	.204042940	1539.6723	1502.4916	.1012255606+01 0. 0. 0. 0.
45	.203927701	1540.5424	1502.6258	.1012494486+01 0. 0. 0. 0.
46	.203812890	1541.4102	1502.7650	.1012730766-01 0. 0. 0. 0.
47	.203698514	1542.2757	1502.9104	.1012964106+01 0. 0. 0. 0.
48	.203584580	1543.1388	1503.0596	.1013195256+01 0. 0. 0. 0.
49	.203471085	1543.9996	1503.2120	.1013424366+01 0. 0. 0. 0.
50	.203358035	1544.8579	1503.3699	.1013650726+01 .6711712776-16 0. 0. 0.

51	.203245433	1545.7138	1503.5302	.101387535E+01 .178313358E-16 0. 0. 0.
52	.203133270	1546 5673	1503.6904	.101409906E+01 .278639986E-15 0. 0. 0.
53	.203021547	1547.4183	1503.8591	.101431923E+01 .385942629E-14 .141868622E-19 0. 0.
54	.202910280	1548.2669	1504.0322	.101453655E+01 .486512197E-13 .372687306E-18 0. 0.
55	.202799455	1549.1130	1504.2025	.101475409E+01 .559769306E-12 .628755545E-17 0. 0.
56	.202689068	1549.9566	1504.3776	.101496905E+01 .586951695E-11 .733597534E-16 0. 0.
57	.202579124	1550.7978	1504.5567	.101518177E+01 .559617162E-10 .756874851E-15 .465975273E-20 .528341169E-20
58	.202469616	1551.6366	1504.7334	.101539438E+01 .463921346E-09 .704550649E-14 .471102506E-19 .534429446E-19
59	.202360538	1552.4730	1504.9159	.101560408E-01 .378664237E-08

				.593501193E-13 .431216473E-18 .469433057E-18
60	.202251899	1553.3069	1505.1027	.101581141E+01 .267164828E-07 .450816020E-12 .356085785E-17 .404366496E-17
61	.202143694	1554.1383	1505.2897	.101601766E+01 .169246168E-06 .307479486E-11 .264164170E-16 .300134970E-16
62	.202035919	1554.9674	1505.4796	.101622133E+01 .958040456E-06 .187406181E-10 .175216504E-15 .199177122E-15
63	.201928572	1555.7940	1505.6708	.101642063E+01 .481570921E-05 .101435324E-09 .103265256E-14 .117446481E-14
64	.201821650	1556.6183	1505.8630	.101662603E+01 .213229565E-04 .483651857E-09 .536443156E-14 .610422358E-14
65	.201715140	1557.4402	1506.0469	.101674895E+01 .822408325E-04 .208691028E-08 .242908985E-13 .276548214E-13
66	.201608995	1558.2602	1506.1913	.101677570E+01 .271949220E-03 .715474130E-08 .943763623E-13 .107500595E-12
67	.201503035	1559.0796	1506.1797	.101656232E+01 .754362002E-03 .213506117E-07 .307927079E-12 .350926183E-12

66	.201396738	1559.9024	1505.7967	.101599440E+01 .171755596E-02 .524744402E-07 .826251726E-12 .942110374E-12
69	.201289147	1560.7362	1504.8423	.101512304E+01 .318312435E-02 .124966062E-06 .161095645E-11 .206596094E-11
70	.201179063	1561.5903	1503.2999	.101421979E+01 .488695365E-02 .174314758E-06 .330624690E-11 .377380784E-11
71	.201065535	1562.4720	1501.4005	.101356461E+01 .647468547E-02 .250534903E-06 .524666259E-11 .599191684E-11
72	.200948140	1563.3848	1499.3953	.101326804E+01 .775186083E-02 .326449635E-06 .758515941E-11 .865750651E-11
73	.200826855	1564.3290	1497.4303	.101329289E+01 .870599499E-02 .400334602E-06 .103737586E-10 .118609975E-10
74	.200701852	1565.3033	1495.5573	.101355160E+01 .942603407E-02 .473819841E-06 .137646960E-10 .157476518E-10
75	.200573347	1566.3061	1493.7778	.101396704E+01 .992848800E-02 .549606521E-06 .179954106E-10 .206007548E-10
76	.200441542	1567.3361	1492.0796	.101448119E+01 .103342806E-01 .630573263E-06

				.233973119E-10
				.268020030E-10
77	.200306609	1568.3919	1490.4454	.121525747E+01
				.106654851E-01
				.719467742E-06
				.324234793E-10
				.348736573E-10
78	.200168687	1569.4726	1488.8615	.121567135E+01
				.109510135E-01
				.819087165E-06
				.397650932E-10
				.455436061E-10
79	.200027889	1570.5773	1487.3167	.121630635E+01
				.111210076E-01
				.932426762E-06
				.521358843E-10
				.598441023E-10
80	.199884311	1571.7055	1485.8021	.121695138E+01
				.114587582E-01
				.106284283E-05
				.690004452E-10
				.792503154E-10
81	.199738030	1572.8565	1484.3112	.121759652E+01
				.117249032E-01
				.121423163E-05
				.921737595E-10
				.105953499E-09
82	.199589112	1574.0301	1482.8381	.121824223E+01
				.119565506E-01
				.139122264E-05
				.124431934E-09
				.143140179E-09
83	.199437612	1575.2256	1481.3786	.121887781E+01
				.122197637E-01
				.159945681E-05
				.169958278E-09
				.195659213E-09
84	.199283579	1576.4433	1479.9301	.121952064E+01
				.124999659E-01
				.184590895E-05
				.235168085E-09
				.270938777E-09

85	.199127057	1577.6825	1478.4895	.102210725E+0 .128015712E-0 .213915818E-0 .330071564E-0 .380576692E-0
86	.198968081	1578.9430	1477.0548	.102069409E+0 .131287932E-0 .246992404E-0 .472631171E-0 .543078389E-0
87	.198806687	1580.2248	1475.6246	.102125696E+0 .134861846E-0 .251176074E-0 .582924250E-0 .786694065E-0
88	.198642905	1581.5277	1474.1975	.102179182E+0 .138782548E-0 .342179765E-0 .101068569E-0 .116818815E-0
89	.198476764	1582.8516	1472.7729	.102229367E+0 .143100623E-0 .424195030E-0 .152961224E-0 .176947775E-0
90	.198308291	1584.1963	1471.3504	.102275726E+0 .147872165E-0 .480237458E-0 .237554154E-0 .275042553E-0
91	.198137513	1585.5618	1469.9297	.102317653E+0 .153152179E-0 .573364503E-0 .380310312E-0 .440712432E-0
92	.197964456	1586.9478	1468.5108	.102354439E+0 .159015568E-0 .688982930E-0 .631565799E-0 .732524535E-0
93	.197789147	1588.3544	1467.0944	.102385281E+0 .165538404E-0 .833322144E-0 .109770005E-0

				.127432460E-07
94	.197611612	1589.7814	1465.6810	.122409249E+01 .172809463E-01 .121524736E-04 .202395347E-07 .235177706E-07
95	.197431879	1591.2287	1464.2717	.102425265E+01 .180928889E-01 .124773923E-04 .404681550E-07 .470668045E-07
96	.197249979	1592.6961	1462.6681	.102432184E+01 .180088945E-01 .155257931E-04 .912920042E-07 .106278683E-06
97	.197065946	1594.1834	1461.4720	.102428571E+01 .200173855E-01 .158027994E-04 .252649892E-06 .294408996E-06
98	.196879814	1595.6906	1460.0861	.102412699E+01 .211558896E-01 .177396201E-04 .108555374E-05 .126621723E-05
99	.196691630	1597.2173	1458.7316	.102368514E+01 .224321025E-01 .150844191E-03 .327502733E-04 .382397031E-04
100	.196640695	1597.6310	1599.5306	.206916468E-03 .262987249E-04 .809814373E+00 .225593247E+00 .263470087E+00
101	.196501414	1598.7634	1457.3538	.122338921E+01 .238453197E-01 .559579854E-04 .653836565E-05 .765740885E-05
102	.196309246	1600.3284	1456.0106	.122810391E+01

				.254278849E-01 .502661359E-04 .146056182E-05 .173221670E-05
103	.196115164	1601.9122	1454.6904	.102204762E+01 .271732619E-01 .606623313E-04 .822841089E-06 .963686894E-06
104	.195919228	1603.5142	1453.3937	.102111765E+01 .292787911E-01 .762028982E-04 .613179770E-26 .718692807E-06
105	.195721494	1605.1342	1452.1212	.102003901E+01 .311252235E-01 .966621573E-04 .532551724E-06 .625029540E-06
106	.195522021	1606.7718	1450.8708	.101885385E+01 .332702561E-21 .123607390E-03 .507887788E-06 .596726012E-06
107	.195320856	1608.4266	1449.6365	.101763621E+01 .354407474E-21 .157675188E-03 .515121939E-06 .605667049E-26
108	.195118029	1610.0986	1448.4064	.101649860E+21 .375272171E-01 .200317095E-03 .544561427E-06 .641222693E-06
109	.194913543	1611.7878	1447.1623	.101559118E+01 .393853125E-01 .252544734E-03 .591586577E-06 .697375563E-06
110	.194707363	1613.4945	1445.8799	.101508799E+01 .406496357E-01 .314845566E-03 .653399394E-06 .771116000E-06

111	.194499409	1615.2196	1444.5324	.1.1515739E+01 .417625306E-21 .386955703E-03 .727748766E-06 .659847566E-26
112	.194289556	1616.9642	1443.2953	.101592065E+01 .422133996E-21 .467837326E-03 .812591685E-26 .961209747E-06
113	.194077645	1618.7298	1441.5526	.101741433E+01 .415738824E-21 .555968427E-23 .906336213E-06 .107336687E-05
114	.193863504	1620.5178	1439.9018	.101957277E+01 .405128863E-21 .649932392E-03 .102843676E-05 .119571685E-05
115	.193646974	1622.3298	1438.1534	.102224219E+01 .389615622E-01 .749110615E-23 .112003918E-05 .132966417E-05
116	.193427923	1624.1671	1436.3284	.102521875E+01 .371757977E-01 .854247769E-03 .124447129E-25 .147921524E-05
117	.193206266	1626.0304	1434.4525	.102829266E+01 .352937746E-01 .967763097E-03 .138754642E-25 .165135607E-05
118	.192981961	1627.9204	1432.5512	.103128092E+01 .335049340E-01 .109386846E-02 .155785373E-25 .185641811E-05
119	.192755008	1629.8371	1430.6460	.103404210E+01 .319363052E-01

				.123865417E-02 .176726243E-05 .210872672E-05
120	.192525440	1631.7805	1428.7557	.103647465E+01 .326742426E-01 .141035771E-02 .203209455E-05 .242791130E-05
121	.192293318	1633.7503	1426.8947	.103850634E+01 .297741636E-01 .161995307E-02 .237461528E-05 .284122528E-05
122	.192058722	1635.7459	1425.0758	.104008012E+01 .292731624E-01 .188222359E-02 .282737236E-05 .336726272E-05
123	.191821752	1637.7666	1423.3117	.104113991E+01 .292015585E-01 .221752157E-02 .343614277E-05 .412229438E-05
124	.191582529	1639.8117	1421.6173	.104161743E+01 .295928036E-01 .265435652E-02 .426999929E-05 .512987679E-05
125	.191341197	1641.8799	1420.0118	.104141983E+01 .302907758E-01 .323365437E-02 .543321716E-05 .653666017E-05
126	.191097933	1643.9704	1418.5206	.104041820E+01 .319543657E-01 .401453204E-02 .7x859915eE-05 .853743628E-05
127	.190852960	1646.0801	1417.1782	.103843870E+01 .340571874E-01 .5x82727161E-02 .947649953E-05 .114343270E-04

128	.190606555	1648.2081	1416.0287	.103526284E+01 .368762422E-01 .656079943E-02 .129882025E-04 .156947616E-04
129	.190359068	1650.3509	1415.1236	.103065608E+01 .424564357E-01 .861626864E-02 .182000256E-04 .220255639E-04
130	.190110917	1652.5051	1414.5077	.102446544E+01 .447256624E-01 .114542451E-01 .259328225E-04 .314310954E-04
131	.189862555	1654.6668	1414.1816	.101685196E+01 .493327484E-01 .152619837E-01 .371906826E-04 .451442822E-04
132	.189614344	1656.8328	1414.0314	.100868629E-01 .534331689E-01 .200561831E-01 .528035427E-04 .641939005E-04
133	.189366325	1659.0028	1413.7553	.100187951E+01 .556345782E-01 .254368792E-01 .726111405E-04 .884095659E-04
134	.189117952	1661.1816	1412.9056	.999967556E+00 .545173367E-01 .324680425E-01 .946259002E-04 .115392076E-03
135	.188868054	1663.3796	1411.1448	.100153150E+01 .497269152E-01 .340642182E-01 .115521903E-03 .141093857E-03
136	.188615254	1665.6090	1408.5225	.100877831E+01 .425224280E-01 .357489155E-01

				.132899784E-03 .162576451E-03
137	.188358556	1667.8789	1405.4276	.101612665E+01 .349111216E-01 .359476018E-01 .147091648E-03 .160229398E-03
138	.188097632	1670.1926	1402.2928	.102702119E+01 .283959486E-01 .355422418E-01 .160694526E-03 .197223542E-03
139	.187832708	1672.5462	1399.4233	.103392753E+01 .235862029E-01 .353333631E-01 .177155782E-03 .217795175E-03
140	.187564321	1674.9415	1396.9203	.103516526E+01 .205143187E-01 .358916425E-01 .200126124E-03 .246460014E-03
141	.187293158	1677.3665	1394.8562	.103952783E+01 .192299887E-01 .376153226E-01 .233724129E-03 .286342264E-03
142	.187020010	1679.8163	1393.3364	.103762323E+01 .192252795E-01 .408485561E-01 .283146076E-03 .349935253E-03
143	.186745787	1682.2830	1392.4199	.103216691E+01 .205084482E-01 .459233439E-01 .354925508E-03 .439435029E-03
144	.186471531	1684.7573	1392.1587	.102953671E+01 .235463337E-01 .529726781E-01 .455390292E-03 .564641468E-03

145	.186198271	1687.2298	1392.4215	.101287408E+01 .279950258E-01 .612550366E-01 .584183119E-03 .725904106E-03
146	.185926540	1689.6956	1392.6206	.999441648E+00 .329612687E-01 .680887782E-01 .720923809E-03 .897444510E-03
147	.185655537	1692.1621	1391.6777	.994843211E+00 .365349022E-01 .701836611E-01 .818550632E-03 .122087023E-02
148	.185382807	1694.6516	1386.6897	.100136071E+01 .369667157E-01 .651779968E-01 .833522039E-03 .104139762E-02
149	.185105445	1697.1908	1384.4102	.101647976E+01 .344468667E-01 .552471432E-01 .770903862E-03 .965005945E-03
150	.184821779	1699.7957	1379.5635	.103383861E+01 .306919364E-01 .445612352E-01 .674730684E-03 .846260651E-03
151	.184531694	1702.4678	1375.0378	.104900065E+01 .271847130E-01 .357215142E-01 .563017535E-03 .732696558E-03
152	.184235897	1705.2012	1371.0694	.106063693E+01 .245432658E-01 .293198351E-01 .511790990E-03 .644506429E-03
153	.183935266	1707.9882	1367.6216	.106920350E+01 .228447266E-01 .250300126E-01 .463273029E-03

				.584634861E-0
154	.183630577	1710.8222	1364.5920	.167472820E+0 .219863715E-0 .223671622E-0 .435090967E-0 .550249695E-0
155	.183322471	1713.6975	1361.8925	.167834422E+0 .216531043E-0 .209490899E-0 .424596411E-0 .536152622E-0
156	.183011483	1716.6096	1359.4664	.168019370E+0 .223665418E-0 .205345523E-0 .430222287E-0 .546471150E-0
157	.182698090	1719.5542	1357.2854	.168044993E+0 .234872624E-0 .209994462E-0 .451573757E-0 .574914628E-0
158	.182382758	1722.5272	1355.3414	.167917159E+0 .251982930E-0 .223225051E-0 .489408205E-0 .624516278E-0
159	.182065957	1725.5245	1353.6344	.167658140E+0 .274725128E-0 .244446329E-0 .544879202E-0 .696906509E-0
160	.181748162	1728.5416	1352.1531	.167219364E+0 .302158296E-0 .274074544E-0 .618466502E-0 .792879768E-0
161	.181429798	1731.5748	1350.8436	.166721909E-0 .331805869E-0 .310521273E-0 .707765141E-0 .909508391E-0
162	.181111118	1734.6216	1349.5687	.166180586E-0

				.358780531E-01 .349850254E-01 .8e44102e7E-03 .103616984E-02
163	.180792003	1737.6834	1348.0912	.105811531E+01 .375921077E-01 .384804443E-01 .892154643E-03 .115196334E-02
164	.180471807	1740.7664	1346.1352	.105767683E+01 .376329144E-01 .406422613E-01 .950352368E-03 .123009921E-02
165	.180149402	1743.8818	1343.5341	.106142234E+01 .357718737E-01 .406601813E-01 .964395140E-03 .125136261E-02
166	.179823530	1747.0420	1340.3457	.106880356E+01 .324615242E-01 .392113451E-01 .935293144E-03 .1216658961E-02
167	.179493229	1750.2569	1336.8046	.1078175971E+01 .265580810E-01 .363725313E-01 .878159792E-03 .114527962E-02
168	.179158052	1753.5314	1333.1700	.1087e1294E+01 .248390215E-01 .331629721E-01 .811987852E-03 .1061665031E-02
169	.178818012	1756.8659	1329.6205	.109656981E+01 .217517293E-01 .301867117E-01 .750887975E-03 .9845213171E-03
170	.178473391	1760.2583	1326.2409	.110393353E+01 .194461586E-01 .277593934E-01 .702991673E-03 .9242627741E-03

171	.178124590	1763.7052	1323.0557	.110978670E+01 .179091665E-01 .259948330E-01 .671533175E-03 .885386572E-03
172	.177772037	1767.2029	1320.0629	.111417677E+01 .178739717E-01 .249095351E-01 .657650933E-03 .869571568E-03
173	.177416156	1770.7478	1317.2554	.111717525E+01 .168796566E-01 .244928619E-01 .661984943E-03 .877862582E-03
174	.177057367	1774.3360	1314.6318	.111881061E+01 .172961591E-01 .247434783E-01 .685600829E-03 .911881464E-03
175	.176696108	1777.9637	1312.2003	.111904480E+01 .183310963E-01 .256835530E-01 .730402587E-03 .974405884E-03
176	.176332853	1781.6264	1309.9784	.111777955E+01 .200254407E-01 .273567837E-01 .789127903E-03 .106936024E-02
177	.175968127	1785.3191	1307.9870	.111490113E+01 .224344219E-01 .298060720E-01 .894718616E-03 .120099826E-02
178	.175602503	1789.0364	1306.2337	.111039596E+01 .255792133E-01 .330157313E-01 .101847578E-02 .137142160E-02
179	.175236535	1792.7726	1304.6791	.110458307E+01 .293480273E-01

				.367983062E-01 .116615164E-02 .157526665E-02
180	.174870598	1796.5242	1303.1863	.109844925E+01 .333460000E-01 .406381206E-01 .132206051E-02 .179162528E-02
181	.174504615	1800.2920	1301.4871	.109385005E+01 .366036885E-01 .436135468E-01 .145509532E-02 .197628141E-02
182	.174137783	1804.0844	1299.2442	.109304709E+01 .367313344E-01 .446507539E-01 .152586130E-02 .206129816E-02
183	.173768604	1807.9173	1296.2412	.109740793E+01 .384867898E-01 .431643625E-01 .150876971E-02 .206484760E-02
184	.173395354	1811.6090	1292.5447	.110634597E+01 .362481845E-01 .395353770E-01 .141134284E-02 .193808980E-02
185	.173016725	1815.7740	1286.4449	.111777986E+01 .328625047E-01 .348339239E-01 .126786715E-02 .174714087E-02
186	.172632133	1819.8192	1284.2517	.112954761E+01 .292541071E-01 .301149912E-01 .111554787E-02 .154274773E-02
187	.172241609	1823.9453	1280.1620	.114029980E+01 .260248666E-01 .260058659E-01 .978504600E-03 .135019687E-02

188	.171845517	1828.1493	1276.2546	.114951707E+01 .234255959E-01 .227238681E-01 .666717183E-03 .120756508E-02
189	.171444330	1832.4273	1272.5374	.115716957E+01 .214915364E-01 .202549284E-01 .781526415E-03 .116307326E-02
190	.171038516	1836.7750	1268.9902	.116342096E+01 .201674421E-01 .184998755E-01 .720661622E-03 .101195159E-02
191	.170628492	1841.1886	1265.5873	.116846659E+01 .193784942E-01 .173513612E-01 .681199872E-03 .960370748E-03
192	.170214626	1845.6655	1262.3273	.117246614E+01 .192609316E-01 .167243378E-01 .660610716E-03 .935179134E-03
193	.169797249	1850.2023	1259.1366	.117552359E+01 .191718942E-01 .165640495E-01 .657379016E-03 .934514594E-03
194	.169376676	1854.7965	1256.0693	.117768612E+01 .196903231E-01 .166459862E-01 .670988037E-03 .957947767E-03
195	.168953221	1859.4453	1253.1067	.117895021E+01 .206138607E-01 .175728007E-01 .701895218E-03 .100644606E-02
196	.168527217	1864.1456	1250.2560	.117927296E+01 .219530695E-01 .187696645E-01

				.751405263E-03
				.108223092E-02
197	.168099024	1868.8940	1247.5277	.117859287E+01
				.237222985E-01
				.244756580E-01
				.821383720E-03
				.115837139E-02
198	.167669038	1873.6868	1244.9309	.117687049E+01
				.259095717E-01
				.227276255E-01
				.913613881E-03
				.132788948E-02
199	.167237667	1878.5198	1242.4630	.117416391E+01
				.264614225E-01
				.255243222E-01
				.102847813E-02
				.150182398E-02
200	.166825280	1883.3892	1240.0945	.117074944E+01
				.312108984E-01
				.287713375E-01
				.116266411E-02
				.170582129E-02
201	.166372096	1888.2930	1237.7485	.116726330E+01
				.338339870E-01
				.322063950E-01
				.130614559E-02
				.192555669E-02
202	.165938030	1893.2325	1235.2904	.116476040E+01
				.359426066E-01
				.353551864E-01
				.144021176E-02
				.213357431E-02
203	.165502546	1898.2141	1232.5506	.116451106E+01
				.367220753E-01
				.376036622E-01
				.154010689E-02
				.229289166E-02
204	.165064638	1903.2500	1229.3924	.116747086E+01
				.360778860E-01
				.384355714E-01
				.158442755E-02
				.237081088E-02

205	.164623046	1908.3553	1225.7860	.117373055E+ .340530194E- .377108949E- .156651953E- .235613472E-
206	.164176603	1913.5447	1221.8244	.118244857E+ .311043072E- .357411008E- .149800058E- .226501685E-
207	.163724531	1918.6283	1217.6648	.119233874E+ .278486083E- .330918993E- .140122923E- .213022222E-
208	.163266517	1924.2112	1213.4534	.120225181E+ .247870245E- .303094250E- .129833492E- .198483045E-
209	.162802616	1929.6942	1209.2873	.121145372E+ .222071103E- .277688293E- .120492775E- .185261465E-
210	.162333103	1935.2754	1205.2148	.121960155E+ .202175172E- .256657723E- .112954824E- .174696171E-
211	.161858349	1940.9519	1201.2527	.122659965E+ .188241642E- .240736014E- .127586271E- .167400676E-
212	.161378753	1946.7201	1197.4025	.123246541E+ .179929618E- .230236563E- .124507956E- .163620844E-
213	.160894714	1952.5767	1193.6618	.123724228E+ .176072489E- .224468702E- .123766658E-

				.163494485E-02
214	.160406628	1958.5180	1190.0304	.124095334E+01 .178862029E-01 .223971555E-01 .125436039E-02 .167208106E-02
215	.159914900	1964.5403	1186.5127	.124358032E+01 .185922367E-01 .228625234E-01 .129666624E-02 .175081534E-02
216	.159419964	1970.6394	1183.1193	.124525920E+01 .193188852E-01 .238679408E-01 .116713075E-02 .167602272E-02
217	.158922296	1976.8105	1179.8650	.124529047E+01 .216522921E-01 .254501964E-01 .126893120E-02 .205387278E-02
218	.158422429	1983.0479	1176.7652	.124417902E+01 .240945355E-01 .276403318E-01 .140519912E-02 .229665201E-02
219	.157920935	1989.3453	1173.8251	.124171829E+01 .271757570E-01 .304243712E-01 .157680956E-02 .258910056E-02
220	.157418369	1995.6964	1171.0198	.123915144E+01 .307978842E-01 .336722459E-01 .177637171E-02 .294172199E-02
221	.156915119	2002.0969	1168.2659	.123419582E+01 .346555216E-01 .370416891E-01 .199245176E-02 .332075267E-02
222	.156411172	2008.5475	1165.3998	.123120141E+01

				.381571676E-01 .399182509E-01 .218526295E-01 .367018579E-01
223	.155905860	2015.0575	1162.1999	.123094602E+01 .425067784E-01 .415220380E-01 .231155423E-02 .391277156E-02
224	.155397791	2021.6456	1158.4797	.123486940E-01 .410395024E-01 .412570314E-01 .233366421E-02 .396197864E-02
225	.154885152	2028.3369	1154.2004	.124317673E+01 .396294954E-01 .399961274E-01 .224492603E-02 .386223215E-02
226	.154366277	2035.1548	1149.4934	.125469356E+01 .367732983E-01 .356150021E-01 .207411514E-02 .359678706E-02
227	.153840097	2042.1156	1144.5687	.126763867E+01 .332573894E-01 .316274918E-01 .186633965E-02 .326681375E-02
228	.153306237	2049.2269	1139.6067	.128050956E+01 .297604630E-01 .277946890E-01 .166035847E-02 .293276608E-02
229	.152764823	2056.4896	1134.7133	.129244161E+01 .266832611E-01 .244804679E-01 .147898588E-02 .263704575E-02
230	.152216242	2063.9011	1129.9301	.130311164E+01 .241839552E-01 .218068057E-01 .133120777E-02 .239671703E-02

231	.151660962	2071.4577	1125.2613	.131250716E+01 .222780168E-01 .197619878E-01 .121794865E-02 .221492410E-02
232	.151099447	2079.1556	1120.6960	.132374275E+01 .209201847E-01 .192830261E-01 .113676427E-02 .208883211E-02
233	.150532113	2086.9917	1116.2199	.132795624E+01 .202514735E-01 .173088795E-01 .108455347E-02 .201434879E-02
234	.149959338	2094.9630	1111.8215	.133426104E+01 .196211666E-01 .167604348E-01 .105684453E-02 .196846223E-02
235	.149381466	2103.0672	1107.4944	.133972791E+01 .195952349E-01 .166277073E-01 .105633138E-02 .201031007E-02
236	.148798830	2111.3020	1103.2378	.134437972E+01 .199585047E-01 .168916821E-01 .108306322E-02 .208170130E-02
237	.148211769	2119.6648	1099.0567	.134819125E+01 .207141561E-01 .175643830E-01 .113464295E-02 .220746747E-02
238	.147620654	2128.1525	1094.9626	.135109052E+01 .218815647E-01 .186801922E-01 .121027993E-02 .239575966E-02
239	.147025903	2136.7613	1090.9722	.135296844E+01 .234911472E-01

				.2029321111E-01 .1331921422E-02 .2656136061E-02
240	.146428000	2145.4863	1087.1257	.1353696881E-01 .2557341941E-01 .2246959971E-01 .1457757581E-02 .3209206341E-02
241	.145827492	2154.3212	1083.3824	.1353178071E+01 .2813587351E-01 .2526772901E-01 .1689202201E-02 .3463344661E-02
242	.145224968	2163.2593	1079.8087	.1351443401E+01 .3112222371E-01 .2869539821E-01 .1938152701E-02 .4032870641E-02
243	.144620962	2172.2941	1076.3583	.1348820881E+01 .3433498611E-01 .3263455211E-01 .2229338351E-02 .4704567071E-02
244	.144015772	2181.4226	1072.9455	.1346139711E+01 .3736734221E-01 .3674326721E-01 .2541244751E-02 .5443912241E-02
245	.143409211	2190.6491	1069.4089	.1344816161E+01 .3967837641E-01 .4042210221E-01 .2852152791E-02 .6161712721E-02
246	.142802351	2199.9894	1065.5397	.1346549341E+01 .4055627241E-01 .4263027301E-01 .3146528041E-02 .6734877381E-02
247	.142197536	2209.4712	1061.1708	.1352545401E+01 .3966425261E-01 .4342627591E-01 .3138117921E-02 .7153187191E-02

248	.141568761	2219.1285	1056.2721	.136277285E+01 .371791437E-01 .421226745E-01 .329633404E-02 .7x8014834E-02
249	.140942270	2228.9925	1050.9633	.137597691E+01 .337391756E-01 .394216716E-01 .295147205E-02 .687134462E-02
250	.140306980	2239.0851	1045.4336	.139043721E+01 .338899776E-01 .366734193E-01 .275440079E-02 .653435669E-02
251	.139662538	2249.4166	1039.8502	.140472997E+01 .287869623E-01 .3x7291739E-01 .255163186E-02 .617438702E-02
252	.139009124	2259.9922	1034.3201	.141821391E+01 .241179594E-01 .297921966E-01 .237462208E-02 .5x6571237E-02
253	.138347209	2270.8031	1028.8963	.142992933E+01 .221732626E-01 .274464987E-01 .223865764E-02 .565119134E-02
254	.137677379	2281.8513	1023.6000	.144038876E+01 .2x943926EE-01 .257x424241-01 .215050312E-02 .555371650E-02
255	.137000250	2293.1291	1018.4404	.144940588E+01 .203928303E-01 .246808924E-01 .211265678E-02 .5587974341-02
256	.136316448	2304.6321	1013.4263	.145699265E+01 .2049367CCE-01 .2424163C1E-01

				.2127001791E-02 .5765902161E-02
257	.135626616	2316.3541	1008.5741	.1463186611E+01 .2124870971E-01 .2442503581E-01 .2196712391E-02 .5117198361E-02
258	.134931451	2328.2879	1003.9107	.1467632151E+01 .2269399881E-01 .2525193261E-01 .2327257671E-02 .6662040631E-02
259	.134231737	2340.4246	999.4738	.1472377771E+01 .2489382691E-01 .2676199861E-01 .2525125501E-02 .7442569151E-02
260	.133528373	2352.7529	995.3266	.1477149231E+01 .2791780221E-01 .2899299491E-01 .2797761441E-02 .8561231121E-02
261	.132822356	2365.2589	991.4367	.1482872921E+01 .3177765601E-01 .3197873051E-01 .3146199361E-02 .9673385501E-02
262	.132114662	2377.9269	987.8463	.1488899791E+01 .3631661611E-01 .3539655961E-01 .3554539931E-02 .1153699591E-01
263	.131405942	2390.7539	984.3853	.1494379111E+01 .4103037451E-01 .3993928031E-01 .3975147901E-02 .1337263421E-01
264	.130696019	2403.7401	980.7393	.1501835911E+01 .4498711691E-01 .4176403921E-01 .4316573631E-02 .1509386351E-01

265	.129983376	2416.9188	976.4738	.146505062E+01 .469543097E-01 .427944372E-01 .447633001E-02 .162663150E-01
266	.129265173	2430.3473	971.2652	.147522006E+01 .462559175E-01 .415999468E-01 .438241938E-02 .166167381E-01
267	.128538102	2444.0945	965.1266	.149121911E-01 .431339718E-01 .384594818E-01 .426448311E-02 .161252101E-01
268	.127799573	2458.2184	958.3822	.151126061E-01 .386513681E-01 .343307311E-01 .362355696E-02 .151654698E-01
269	.127048349	2472.7536	951.4273	.153174833E-01 .339581347E-01 .301918924E-01 .316665785E-02 .139274597E-01
270	.126284389	2487.7126	944.5477	.155130243E-01 .297972730E-01 .266551693E-01 .276229783E-02 .128815895E-01
271	.125508352	2503.2945	937.8912	.156865613E-01 .264917273E-01 .239672120E-01 .243630524E-02 .121264337E-01
272	.124721191	2518.8924	931.5203	.158415769E-01 .240978836E-01 .221693243E-01 .219613926E-02 .117365485E-01
273	.123923950	2535.0973	925.4726	.159715785E-01 .225751849E-01 .212397385E-01 .213576278E-02

				.117618779E-01
274	.123117726	2551.6981	919.7919	.162774926E-01 .216826745E-01 .211797666E-21 .194413966E-02 .122701630E-01
275	.122303747	2568.6806	914.5814	.161558553E-01 .220510792E-01 .220646492E-01 .191920128E-02 .133847044E-01
276	.121483529	2586.0235	912.2222	.161991698E-01 .231160474E-01 .240835656E-01 .195990624E-02 .153291365E-01
277	.120659138	2603.6923	906.4239	.161939707E-01 .253436654E-01 .275765315E-01 .226885592E-02 .174926[illegible]E-01
278	.119833554	2621.6302	904.3056	.161198[illegible]E-01 .[illegible]E-01 .[illegible]E-01 .224340981E-02 .[illegible]E-01
279	.119011027	2639.7492	904.3796	.159523755E-01 .344246784E-01 .[illegible]E-01 .[illegible]E-02 .313333544E-01
280	.118196866	2657.9323	907.2595	.156516116E-01 .439952888E-01 .[illegible]E-01 .259683434E-02 .429034702E-01
281	.117395322	2676.0799	912.9244	.153727657E-01 .461579434E-01 .577746583E-01 .[illegible]E-02 .[illegible]E-01
282	.116608756	2694.131[illegible]	931.0382	.148670992E-01 .441792699E-01 .549634798E-01 .167289984E-02 .958046740E-01

IV. PLMODE: DOCUMENTATION

The following chapter is extracted from the computer model PLMODE.

PLMODE ARL:UT NORMAL MODE BASED PROPAGATION LOSS MODEL
VERSION 1.2 MARCH 1980

DESIGNED AND IMPLEMENTED BY

SUSAN G. PAYNE

DOCUMENTATION FOR PLMODE IS GIVEN IN

THE ACOUSTIC NORMAL MODE MODEL NEMESIS

BY

RUTH GONZALEZ AND KENNETH E. HAWKER

ARL:UT TECHNICAL REPORT ARL-TR-80-13

AND

USER'S MANUAL FOR NEMESIS AND PLMODE

BY

RUTH GONZALEZ AND SUSAN G. PAYNE

ARL:UT TECHNICAL MEMORANDUM ARL-TM-80-6

APPLIED RESEARCH LABORATORIES

THE UNIVERSITY OF TEXAS AT AUSTIN

SPONSORED BY NORDA CODE 520, NSTL STATION, MISSISSIPPI 39529

OBJECTIVE

USING NORMAL MODE THEORY, THIS MODEL IS DESIGNED TO COMPUTE MODE ATTENUATIONS, COMPLEX VELOCITY POTENTIAL, COHERENT AND INCOHERENT PROPAGATION LOSS, AND PHASE IN A RANGE-INVARIANT ENVIRONMENT.

PHYSICAL DESCRIPTION

PLMODE IS A COMPUTER PROGRAM DESIGNED FOR USE WITH THE ARL:UT NORMAL MODE MODEL, NEMESIS. THIS MODEL ASSUMES A HORIZONTALLY STRATIFIED DEEP OCEAN WITH SINGLE CHANNEL PROFILES AND MULTIPLE FLUID SEDIMENT LAYERS OVERLYING A SUBSTRATE. SOUND SPEEDS IN THE WATER AND SEDIMENT LAYERS VARY WITH DEPTH. THE DENSITY IS CONSTANT WITHIN EACH LAYER. THE LAST LAYER IS A HOMOGENEOUS, SEMI-INFINITE FLUID OR SOLID SUBSTRATE, I.E., THE COMPRESSIONAL AND SHEAR WAVE SPEEDS AND DENSITY REMAIN CONSTANT WITH DEPTH. SOUND SPEEDS AND DENSITIES CAN BE DISCONTINUOUS AT LAYER INTERFACES. THE ATTENUATIONS IN THIS ENVIRONMENT ARE DEFINED IN PLMODE. ATTENUATION IN THE WATER AND THE SHEAR AND COMPRESSIONAL WAVE ATTENUATIONS IN THE SUBSTRATE ARE ASSUMED TO REMAIN CONSTANT WITH DEPTH. COMPRESSIONAL WAVE ATTENUATION IN THE SEDIMENT LAYERS CAN VARY WITH DEPTH, AND CAN BE DISCONTINUOUS AT THE LAYER INTERFACES.

MATHEMATICAL DESCRIPTION

PLMODE REQUIRES INPUT FROM THE MODE MODEL IN ORDER TO OBTAIN THE EIGENVALUES (KN), THE EIGENFUNCTIONS (UN(Z)),AND THE ATTENUATION TERMS IN EACH LAYER (GNL).

THE ATTENUATION TERMS ARE COMPUTED BY AN INTEGRAL DERIVED FROM FIRST ORDER PERTURBATION THEORY (SEE ARL-TR-80-13), ASSUMING THAT THE ATTENUATION IS CONSTANT IN EACH LAYER. IN PLMODE, IT IS ASSUMED THAT THIS IS TRUE IN THE WATER (AW, THE ATTENUATION VALUE IN THE WATER) AND THE SUBSTRATE (AC AND AS, THE COMPRESSIONAL AND SHEAR WAVE ATTENUATIONS, RESPECTIVELY). HOWEVER, THE ATTENUATIONS MAY VARY WITH DEPTH IN THE SEDIMENT LAYERS (AL(Z)).

IF THE SEDIMENT ATTENUATIONS ARE CONSTANT IN EACH LAYER THE MODE ATTENUATION FOR MODE NUMBER N IS COMPUTED AS

$$\text{SUM}_{L}\left(A_L * G_{L,NL} \right) + A_W * G_{W,NW} + A_C * G_{C,NC} + A_S * G_{S,NS}$$

WHERE L REFERS TO A SEDIMENT LAYER, W THE WATER, C THE COMPRESSIONAL WAVE IN THE SUBSTRATE, S THE SHEAR WAVE IN THE SUBSTRATE, AND N THE MODE NUMBER.

IF THE SEDIMENT ATTENUATIONS VARY WITH DEPTH, THEN THE MODE ATTENUATION FOR MODE NUMBER N, ATN, IS COMPUTED AS

$$\text{SUM}_{L}\left(D_L * 2 * PI * F / K_N * INT_L \right) + A_W * G_{W,NW} + A_C * G_{C,NC} + A_S * G_{S,NS}$$

$$INT_L = \text{INTEGRAL}_{DZ}\left(U_N^2(Z) * A_L(Z) / C(Z) \right)$$

WHERE DL IS THE DENSITY OF SEDIMENT LAYER L, F IS FREQUENCY, C(Z) IS THE SOUND SPEED AS FUNCTION OF DEPTH, AND INTEGRAL( )DZ IS THE INTEGRAL WITH RESPECT TO DEPTH.

SINCE THE ATTENUATIONS AW, AC, AS AND AL(Z) ARE INPUT IN DB/M/KHZ THE ATTENUATION SUMS, ATN, HAVE TO BE CONVERTED TO NEPERS/M BEFORE USE IN THE FIELD CALCULATIONS.

$$M_N = AT_N * (F / 1000.) * (LOG_E (10.) / 20.)$$

WHERE MN IS THE ATTENUATION OF THE NTH MODE, AND F IS THE FREQUENCY (IN HERTZ).

THE FOLLOWING EQUATION IS USED TO COMPUTE THE COMPLEX VELOCITY POTENTIAL (VP) FOR A GIVEN SOURCE DEPTH (ZS), GIVEN RECEIVER DEPTH (ZR) AT A RANGE, R,

$$I * PI * Q * D_S * SUM (H_N * U_N (Z_S) * U_N (Z_R) * EXP (-R * M_N))$$

$$Q = 10.^{(SL / 20.)}$$

$$H_N = H_0^1 (K_N * R)$$

WHERE DS IS THE DENSITY OF THE LAYER IN WHICH THE SOURCE LIES, SL IS THE SOURCE LEVEL (DB RE 1 MICROPASCAL AT 1 M), I IS THE COMPLEX NUMBER I, AND H01( ) IS THE HANKEL FUNCTION OF ORDER ZERO, FIRST KIND. THE HANKEL FUNCTION IS APPROXIMATED BY THE FIRST TERM OF THE ASYMPTOTIC EXPANSION,

$$H_0^1 (K_N * R) = SQRT(2 / (PI * K_N * R)) * EXP(-I * (K_N * R - PI / 4)) .$$

THE PROPAGATION LOSS (PL) IS COMPUTED BY

$$PL = -10. * LOG_{10} (ABS(VP)^2) + SL .$$

THE INCOHERENT PROPAGATION LOSS (IPL) IS COMPUTED FROM THE INCOHERENT SUMMATION OF THE MODE TERMS,

$$I * PI * D_S * SUM ((ABS(H_N) * U_N (Z_S) * U_N (Z_R) * EXP (-R * M_N))^2)$$

$$IPL = -10. * LOG_{10} (IMS)$$

WHERE IMS IS THE INCOHERENT MODE SUM.

THE PHASE IS COMPUTED FROM THE COMPLEX VELOCITY POTENTIAL.

$$\text{PHASE} = \text{TAN}^{-1}\left(\text{IM(VP)} \;/\; \text{RL(VP)} \right)$$

WHERE IM(VP) AND RL_{L}(VP) ARE THE IMAGINARY AND REAL PARTS, RESPECTIVELY, OF THE VELOCITY POTENTIAL.

THE MAXIMUM PROPAGATION LOSS IS SET AT 180 DB. IF THE COMPLEX FIELD IS ZERO, THE PHASE IS SET AT 10**99.

ON INPUT

THERE ARE TWO INPUT FILES REQUIRED BY PLMODE - A FORMATTED DATA FILE SUPPLIED BY THE USER, AND THE DISK/TAPE FILE CREATED BY THE NORMAL MODE MODEL NEMESIS.

LFDISK (TAPE1)

THIS IS THE DISK/TAPE FILE CREATED BY THE NORMAL MODE MODEL, NEMESIS. IT CONTAINS ALL THE RELEVANT INPUT DATA SUPPLIED TO NEMESIS TOGETHER WITH THE EIGENVALUES, GROUP VELOCITIES, ATTENUATION TERMS, AND NORMAL MODES. SEE THE DESCRIPTION OF THE FORMAT OF THIS FILE IN THE NEMESIS PROGRAM, OR IN SUBROUTINE INPMOD OF PLMODE.
THIS FILE IS READ BY ROUTINES INPMOD AND GETMOD.

LFINP (TAPE5, INPUT)

THIS IS THE USER-SUPPLIED DATA SET CONTAINING THE DESCRIPTION OF THE ATTENUATION IN THE ENVIRONMENT, AND THE SOURCE/RECEIVER/RANGE GEOMETRIES.
THIS FILE IS READ BY ROUTINES INATTN AND INPSRR.

THE FOLLOWING RESTRICTIONS ARE IMPOSED ON THE INPUT TO PLMODE:

(1) ALL DEPTHS ARE REFERENCED TO THE AIR-WATER INTERFACE, AND NONE CAN FALL IN THE SUBSTRATE.
(2) ATTENUATIONS MUST BE DEFINED FOR EACH LAYER THAT WAS SPECIFIED IN THE NORMAL MODE MODEL.
(3) FOR ATTENUATION PROFILES, ALL DEPTHS MUST BE IN ORDER OF INCREASING DEPTH. THERE MUST BE AT LEAST A DEPTH-ATTENUATION PAIR SPECIFIED ON THE UPPER AND LOWER INTERFACES OF A SEDIMENT LAYER. THE LAST DEPTH AT THE BOTTOM OF A LAYER MUST EQUAL THE FIRST DEPTH AT THE TOP OF THE NEXT LAYER.
THE MAXIMUM NUMBER OF DEPTH-ATTENUATION PAIRS IS 48.
(4) ALL ATTENUATIONS MUST BE INPUT IN DB/METER/KILOHERTZ.
(5) ALL DEPTHS MUST BE INPUT IN METERS, AND MUST BE GREATER THAN 0.
(6) ALL RANGES MUST BE INPUT IN KILOMETERS, AND MUST BE GREATER THAN 0.
(7) THERE ARE NO RESTRICTIONS ON THE NUMBER OF SOURCES, RECEIVERS, OR RANGES THAT CAN BE INPUT IN A DATA SET (BUT SEE -CURRENT LIMITS- BELOW)

INPUT TO PLMODE IS VIA FORMATTED READ STATEMENTS. EACH ITEM MUST BE POSITIONED IN THE CORRECT FIELD AS GIVEN BY THE FORMAT STATEMENT.

CARD NO	COLUMN NO OF CARD	DESCRIPTION OF DATA	FORMAT
1	1-80	HEADER INFORMATION USED TO DESCRIBE DATA	8A10
2	1-10	ATTENUATION IN THE WATER	F10.4
	11-20	COMPRESSIONAL WAVE ATTENUATION IN THE SUBSTRATE	F10.4
	21-30	SHEAR WAVE ATTENUATION IN THE SUBSTRATE	F10.4
IF SEDIMENT LAYERS WERE DEFINED IN NEMESIS: CARDS 3,4 ARE INPUT.			
3	1-4	DESCRIPTION OF THE TYPE OF ATTENUATION INPUT:	1A4
		CONS TO DENOTE CONSTANT ATTENUATION IN EACH SEDIMENT LAYER.	
		PROF TO DENOTE DEPTH-ATTENUATION DESCRIPTION FOR EACH SEDIMENT LAYER	
4A,B..		FOR CONSTANT ATTENUATION (CONS), ATTENUATION IN EACH SEDIMENT LAYER	
	1-10	ATTENUATION FOR FIRST SEDIMENT LAYER	F10.4
	11-20	ATTENUATION FOR SECOND SEDIMENT LAYER	F10.4
	....	....	F10.4
		FOR ATTENUATION PROFILES (PROF), DEPTH-ATTENUATION PAIRS. THERE MUST BE A PAIR DEFINED AT THE TOP AND BOTTOM OF EACH SEDIMENT LAYER	
	1-10	DEPTH	F10.2
	11-20	SEDIMENT ATTENUATION	F10.4
	21-30	DEPTH	F10.2
	31-40	SEDIMENT ATTENUATION	F10.4
	....	....	
5		BLANK CARD AN END-OF-FILE FOLLOWING CARD 5 INDICATES THE END OF THE DATA SET (NO SOURCE/RECEIVER/RANGE INPUT TO COME). CARDS 1-5-EOF CAN BE REPEATED FOR DIFFERENT SETS OF ATTENUATIONS TO COMPUTE MODE ATTENUATIONS ONLY.	

6	1-5	DESIGNATOR OF THE TYPE OF OUTPUT DESIRED. DEPTH TO DENOTE FIELD. PROPAGATION LOSS .VS. DEPTH FOR EACH SOURCE/RANGE COMBINATION RANGE TO DENOTE FIELD. PROPAGATION LOSS .VS. RANGE FOR EACH SOURCE/RECEIVER COMBINATION BOTH TO DENOTE BOTH TYPES OF OUTPUT	1A5
7A,B..		SOURCE DEPTHS	
	1-10	SOURCE DEPTH	F10.2
	11-20	SOURCE DEPTH	F10.2
	...	...	
8		BLANK CARD	
9A,B..		RECEIVER DEPTHS. CAN BE INPUT AS INDIVIDUAL DEPTHS (E.G., 10. 1025.), OR, CAN BE INPUT AS TRIPLETS OF DEPTH INCREMENT (PRECEDED BY A NEGATIVE SIGN), START DEPTH AND STOP DEPTH (E.G., -10. 100. 2000.), OR, CAN BE INPUT AS COMBINATIONS OF THESE TWO FORMS OF INPUT (E.G., 1025. -10. 100. 2000. 10.)	8F10.2
10		BLANK CARD	
11		RANGES. CAN BE INPUT IN THE FORMAT DESCRIBED ABOVE FOR THE RECEIVERS.	8F10.2
12		BLANK CARD CARDS 6-12 CAN BE REPEATED TO INPUT DIFFERENT SOURCE/RECEIVER/RANGE DATA SETS CORRESPONDING TO THE ATTENUATION DATA SET INPUT ON CARDS 1-5. AN END-OF-FILE FOLLOWING CARD 12 INDICATES THE END OF THE ENTIRE DATA SET. THE NEXT CARD TO BE READ FOLLOWING AN END-OF-FILE HERE IS CARD 1.	

ON OUTPUT

LFOUT (TAPE6)

THIS IS THE PRINTED OUTPUT FILE. IT CONTAINS THE GEOACOUSTIC PROFILE DESCRIBING THE ENVIRONMENT, THE MODE ATTENUATION TABLE, THE COMPLEX VELOCITY POTENTIAL, COHERENT AND INCOHERENT PROPAGATION LOSS, AND PHASE FOR EACH SOURCE/RECEIVER/RANGE COMBINATION.
THIS FILE IS WRITTEN ON BY ROUTINES PLOUT, PLOUT1, PLOUT2, PLHEAD, PLPRNT, ALERT, AND ERROR.

THE CHARACTER STRINGS BOD AND EOD (BEGINNING AND END OF DATA) DELINEATE THE START AND END OF EACH TABLE OF OUTPUT. NOTE THAT WHEN THE PHASE OF THE ACOUSTIC FIELD IS INDETERMINATE (COMPLEX FIELD EQUALS ZERO), ITS VALUE IS SET AT 10**99. THIS NUMBER EXCEEDS THE OUTPUT FIELD PROVIDED FOR IN THE FORMAT, AND ON THE CYBER 171, ASTERISKS ARE OUTPUT.

THE FOLLOWING ERROR MESSAGES MAY BE PRINTED ON DETECTION OF AN INPUT OR EXECUTION PROBLEM:

ARRAY SIZE DIAGNOSTICS

INSUFFICIENT SPACE ALLOTTED TO ARRAY ITITLE IN MAIN PROGRAM
THE VALUE OF MAXTLE IN MAIN PROGRAM PLMODE IS TOO SMALL: IT MUST BE GREATER THAN OR EQUAL THE NUMBER OF WORDS IN THE FIRST RECORD ON THE NEMESIS OUTPUT FILE.

INSUFFICIENT SPACE ALLOTTED TO ARRAY BUF
THE DIMENSION OF ARRAY BUF IN SUBROUTINE INPMOD (NBUF) IS TOO SMALL: IT MUST BE GREATER THAN OR EQUAL TO THE MAXIMUM NUMBER OF LAYERS SPECIFIED IN NEMESIS AND THE NUMBER OF WORDS IN THE SECOND RECORD ON THE NEMESIS DISK FILE.

MAX NO. OF LAYERS ON MODE DISK .GT. NO. SET FOR THIS PROGRAM
THE VALUE OF MAXLAY IN MAIN PROGRAM PLMODE IS TOO SMALL: IT MUST BE GREATER THAN OR EQUAL TO THE MAXIMUM NUMBER OF LAYERS SPECIFIED IN NEMESIS.

INSUFFICIENT SPACE IN WORK ARRAY FOR MODES AND ATTENUATIONS
INCREASE THE DIMENSION OF WORK ARRAY (MAXWRK) IN MAIN PROGRAM PLMODE. SEE CURRENT LIMITS (BELOW) AS A GUIDE TO MAXWRK.

MAX NO. OF SVP PTS. ON MODE DISK .GT. NO. SET FOR THIS PROGRAM
THE VALUE OF MAXSVP IN MAIN PROGRAM PLMODE IS TOO SMALL: IT MUST BE GREATER THAN OR EQUAL TO THE MAXIMUM NUMBER OF SOUND SPEED PAIRS SPECIFIED IN NEMESIS.

INSUFFICIENT WORK SPACE WHEN ALLOCATING SPACE FOR ATTEN CALCS.
THE VALUE OF MAXWRK IN MAIN PROGRAM PLMODE IS TOO SMALL:
SEE CURRENT LIMITS (BELOW) AS A GUIDE TO MAXWRK.

INSUFFICIENT SPACE IN ATTENUATION ARRAYS: MUST BE .GE. LAYERS-2
INCREASE THE DIMENSION OF ATTSED, ATTDEP ARRAYS (MAXATT) IN MAIN
PROGRAM PLMODE TO AT LEAST NUMBER OF LAYERS - 2

OVERFLOW IN ATTEN ARRAY ON ASSIGNING ATTEN TO INTERFACES
INCREASE SIZE OF ATTSED AND ATTDEP ARRAYS (MAXATT) IN MAIN
PROGRAM PLMODE TO AT LEAST 2*NUMBER OF SEDIMENT LAYERS

INSUFFICIENT SPACE IN WORK ARRAY FOR SEDIMENT ATTEN CALCS
INCREASE THE DIMENSION OF THE WORK ARRAY (MAXWRK) IN MAIN
PROGRAM PLMODE. SEE CURRENT LIMITS (BELOW) AS A GUIDE TO
MAXWRK.

INPUT DIAGNOSTICS

ERROR DETECTED WHILE READING FROM MODE FILE
PROBLEM WITH THE MODE DISK FILE: CHECK THAT THE FILE HAS THE
CORRECT STRUCTURE, NUMBER, AND SIZE OF RECORDS.

EOF ENCOUNTERED WHILE READING WATER AND SUBSTRATE ATTENUATIONS

NEGATIVE WATER OR SUBSTRATE ATTENUATIONS DETECTED ON INPUT

EOF ENCOUNTERED WHILE READING SEDIMENT ATTENUATION TYPE

UNKNOWN SEDIMENT ATTENUATION TYPE DETECTED (CONS OR PROF ONLY)

EOF ENCOUNTERED WHILE READING SEDIMENT ATTENUATIONS

NEGATIVE SEDIMENT ATTENUATIONS DETECTED

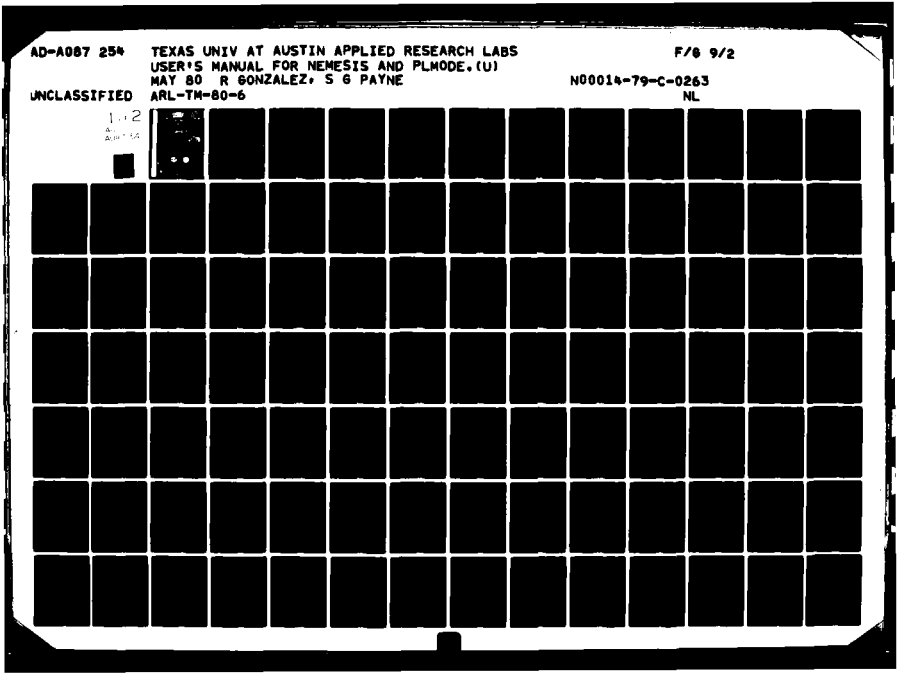
EOF ENCOUNTERED WHILE READING ATTENUATION PROFILE

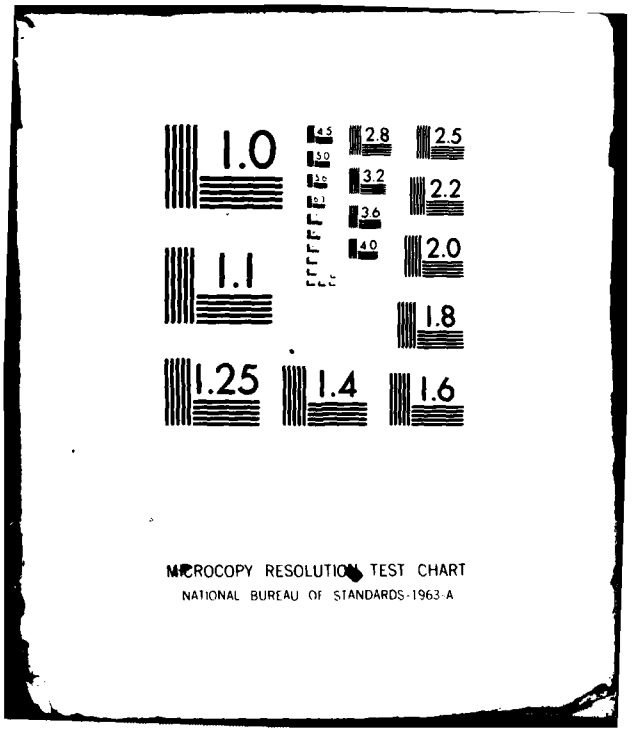
ZERO DEPTH FOUND IN ATTENUATION PROFILE
IF BOTH DEPTH AND ATTEN ARE ZERO, THIS MESSAGE WILL NOT OCCUR; IT
IS EXECUTED ONLY IF DEPTH IS ZERO AND ATTEN IS NON-ZERO.

OVERFLOW IN ATTEN ARRAYS; OR, BLANK CARD MUST FOLLOW ATTENS
INCREASE THE SIZE OF ATTSED, ATTDEP ARRAYS (MAXATT) IN MAIN
PROGRAM, OR REDUCE THE NUMBER OF PROFILE POINTS INPUT.
CHECK THAT A BLANK CARD FOLLOWS THE ATTENUATION INPUT

NEGATIVE VALUES DETECTED IN ATTENUATION PROFILE

AD-A087 254 TEXAS UNIV AT AUSTIN APPLIED RESEARCH LABS F/G 9/2
USER'S MANUAL FOR NEMESIS AND PLMODE.(U)
MAY 80 R GONZALEZ, S G PAYNE N00014-79-C-0263
UNCLASSIFIED ARL-TM-80-6 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

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19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

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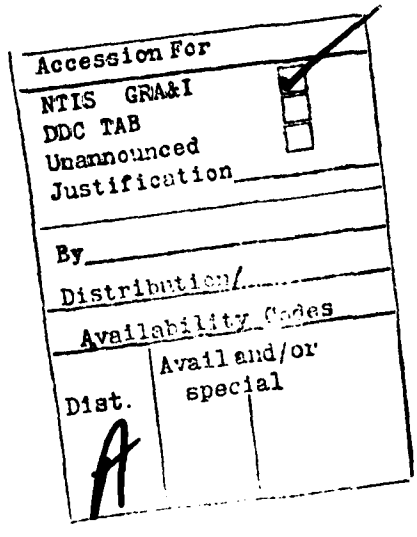
TABLE OF CONTENTS



I. INTRODUCTION

The normal mode model, NEMESIS, was designed and implemented at the Applied Research Laboratories, The University of Texas at Austin (ARL:UT), to aid in the investigation of low frequency, range invariant, acoustic propagation effects. The mathematical basis and numerical scheme of this model are described by Gonzalez and Hawker (1980). NEMESIS computes the eigenvalues and normal modes of the depth separated acoustic wave equation. Group velocities and modal attenuation terms are also computed. Propagation loss and velocity potential for a source and receiver at a given range can be calculated from these quantities (Gonzalez and Hawker, 1980). A computer model, PLMODE, was designed to perform these computations, and the computer code for both NEMESIS and PLMODE was prepared for export to other research laboratories. This report is designed to accompany this software and to assist persons who wish to use it. The contents include descriptions of the modeled environment, the input data and their format, and the output produced by the models. An explanation of the diagnostic messages that may arise during execution of the models is also included. Estimates of memory requirements and execution times are given along with sample data sets and their resulting output.

Although it provides information beyond the scope of a user's manual, an appendix, "Installation Information," has been added to this document to aid in the retrieval of the software from the magnetic tape on which it was written for export.

II. NEMESIS: DOCUMENTATION

The following chapter is extracted from the computer model NEMESIS.

NEMESIS ARL:UT NORMAL MODE MODEL
VERSION 1.2 FEBRUARY 1980

DESIGNED AND IMPLEMENTED BY

RUTH GONZALEZ

DOCUMENTATION FOR NEMESIS IS GIVEN IN

THE ACOUSTIC NORMAL MODE MODEL NEMESIS

BY

RUTH GONZALEZ AND KENNETH F. HAWKER

ARL:UT TECHNICAL REPORT ARL-TR-80-13

AND

USER'S MANUAL FOR NEMESIS AND PLMODE

BY

RUTH GONZALEZ AND SUSAN G. PAYNE

ARL:UT TECHNICAL MEMORANDUM ARL-TM-80-6

THE APPLIED RESEARCH LABORATORIES

THE UNIVERSITY OF TEXAS AT AUSTIN

SPONSORED BY NORDA CODE 520, NSTL STATION, MISSISSIPPI 39529

MATHEMATICAL AND PHYSICAL DESCRIPTION

NEMESIS IS LOW FREQUENCY, RANGE-INVARIANT, WAVE THEORY NORMAL MODE MODEL. IT WAS DESIGNED TO COMPUTE EIGENVALUES AND NORMAL MODES IN A HORIZONTALLY STRATIFIED DEEP OCEAN WITH SINGLE CHANNEL PROFILES AND MULTIPLE FLUID SEDIMENT LAYERS OVERLYING A SUBSTRATE. SOUND SPEEDS IN THE WATER AND SEDIMENT VARY WITH DEPTH. THE DENSITY IS CONSTANT WITHIN EACH LAYER. THE LAST LAYER IS A HOMOGENEOUS, SEMI-INFINITE, FLUID OR SOLID SUBSTRATE, I.E., THE COMPRESSIONAL AND SHEAR SPEEDS AND DENSITY REMAIN CONSTANT WITH DEPTH. SOUND SPEEDS AND DENSITIES CAN BE DISCONTINUOUS AT LAYER INTERFACES. THE MODEL NUMERICALLY COMPUTES THE DISCRETE EIGENVALUES AND EIGENFUNCTIONS, OR NORMAL MODES, OF THE DEPTH SEPARATED ACOUSTIC WAVE EQUATION FOR THIS TYPE OF ENVIRONMENT. THE CONTINUOUS PART OF THE SPECTRUM OF THE SOLUTION IS IGNORED. GROUP VELOCITIES ARE ALSO COMPUTED.

DEPTH EQUATION

$$(D^2 / DZ^2)\, U_N + (K^2(Z) - K_N^2)\, U_N = 0$$

WHERE U_N IS THE EIGENFUNCTION
K_N IS THE EIGENVALUE
$K(Z) = 2*PI*F / C(Z)$
C(Z) IS THE SOUND SPEED
F IS THE SOURCE FREQUENCY

ANY QUESTIONS CONCERNING THE APPLICABILITY OF THE MODEL TO A PARTICULAR SITUATION SHOULD BE DIRECTED TO

KENNETH E. HAWKER
APPLIED RESEARCH LABORATORIES
THE UNIVERSITY OF TEXAS AT AUSTIN
P. O. BOX 8029
AUSTIN, TEXAS 78712
TEL. (512) 835-3407 OR 835-3200

ON INPUT

THE FOLLOWING RESTRICTIONS ARE IMPOSED ON THE INPUT TO NEMESIS

(1) THERE MUST BE AT LEAST 2 LAYERS (WATER AND SUBSTRATE) BUT NO MORE THAN 10.
(2) ALL DEPTHS MUST BE IN INCREASING ORDER.
(3) DEPTHS AT LAYER INTERFACES MUST BE EQUAL, I.E., THE LAST DEPTH AT THE BOTTOM OF A LAYER MUST EQUAL THE FIRST DEPTH AT TOP OF THE NEXT LAYER.
(4) FIRST SPECIFIED DEPTH MUST BE 0 (AIR-SURFACE INTERFACE).
(5) THE SOUND SPEED MINIMUM IN THE WATER AND SEDIMENTS MUST BE LESS THAN THE SHEAR AND COMPRESSIONAL WAVE SPEEDS IN THE SUBSTRATE.
(6) SHEAR SPEED OF ZERO IN THE SUBSTRATE IMPLIES A FLUID SUBSTRATE AND A NONZERO SHEAR SPEED IMPLIES A SOLID SUBSTRATE. NO SHEAR SPEEDS ARE ALLOWED IN THE WATER OR SEDIMENTS.
(7) THE SHEAR SPEED MUST BE LESS THAN THE COMPRESSIONAL WAVE SPEED IN THE SUBSTRATE.
(8) IF A PRESSURE RELEASE BOTTOM IS SPECIFIED, THERE ARE AN INFINITE NUMBER OF MODES. THE COMPRESSIONAL SPEED IS USED AS THE PHASE VELOCITY CUTOFF, IN THIS CASE, AND IS NOT USED IN THE BOUNDARY CONDITIONS.
(9) FOR SOME DATA INPUTS, DEFAULTS ARE GIVEN IN PARENTHESES. THESE CAN BE INVOKED BY LEAVING THE APPROPRIATE DATA FIELD BLANK OR SETTING IT TO ^.
(10) MAXIMUM NUMBER OF DEPTH-SOUND SPEED PAIRS IS 125.
(11) MAXIMUM MODE WHICH CAN BE COMPUTED IS MODE NUMBER 300.
(12) MAXIMUM NUMBER OF MESH POINTS PER MODE IS 2000. THE NUMBER OF MESH POINTS IN A LAYER IS EQUAL TO THE NUMBER OF MESH INTERVALS IN THAT LAYER PLUS 1.
(13) THE NUMBER OF MESH INTERVALS IN EACH LAYER MUST BE EVEN AND GREATER THAN OR EQUAL TO 4. THERE ARE NO MESH INTERVALS IN THE SUBSTRATE. THE SOLUTION IS ANALYTICALLY COMPUTED IN THAT REGION.
(14) ALL QUANTITIES MUST BE SPECIFIED IN THE MKS SYSTEM EXCEPT DENSITY, WHICH IS IN THE CGS SYSTEM.
(15) THE DEPTHS ASSOCIATED WITH BOTH THE COMPRESSIONAL AND SHEAR SPEEDS IN THE SUBSTRATE ARE THE SUBSTRATE INTERFACE DEPTHS. THE COMPRESSIONAL SPEED IS FIRST AND THE SHEAR SPEED IS SECOND.

INPUT TO NEMESIS IS VIA FORMATTED READ STATEMENTS. EACH ITEM MUST BE POSITIONED IN THE CORRECT FIELD AS GIVEN BY THE FORMAT STATEMENT. INTEGER VALUES AND EXPONENTS MUST BE RIGHT-JUSTIFIED IN THEIR FIELD.

CARD NO	COLUMN NO OF CARD	DESCRIPTION OF DATA	FORMAT
1	1-80	HEADER INFORMATION USED TO DESCRIBE DATA	8A10
2	1-10	SOURCE FREQUENCY IN HZ	F10.3
	11-20	DEPTH WHERE THE INTEGRATIONS ARE TO BE MATCHED; MUST BE IN WATER (DEFAULT IS AT SOUND SPEED MINIMUM IN THE WATER OR MIDDLE OF THE WATER COLUMN. DEFAULT IS RECOMMENDED)	F10.3
	21-30	WAVE NUMBER K1	F10.3
	31-40	WAVE NUMBER K2	F10.3
	41-50	WAVE NUMBER INCREMENT. K1, K2, AND INCREMENT ARE FOR ADDITIONAL DIAGNOSTIC INFORMATION. THE DIFFERENTIAL EQUATION IS INTEGRATED USING THE WAVE NUMBERS K1 TO K2 IN THE INCREMENT SPECIFIED IN COLS 41-50. THE DISCONTINUITY IN THE DEPTH DERIVATIVES OF THE TRIAL MODES IS TABULATED FOR EACH WAVE NUMBER. NOT RECOMMENDED UNLESS TRACING CONVERGENCE OF NUMERICAL PROCESS. ALL THREE QUANTITIES MUST BE POSITIVE TO ACTIVATE DIAGNOSTICS	F10.3
3	1-5	LOWEST MODE NUMBER TO BE COMPUTED (DEFAULT IS 1)	I5
	6-10	HIGHEST MODE NUMBER TO BE COMPUTED (DEFAULT IS TO COMPUTE ALL MODES UP TO MODE NUMBER 300)	I5
4		OPTIONS TO BE USED (1=YES, 0=NO)	
	5	CORRECT SOUND SPEEDS FOR CURVATURE OF EARTH	I5
	10	USE PRESSURE RELEASE SUBSTRATE	I5
	15	SUPPRESS CALCULATION OF HIDDEN DEPTHS; NOT RECOMMENDED	I5
	20	TURN ON DIAGNOSTIC PRINTS AS MODES ARE COMPUTED. NOT RECOMMENDED UNLESS TRACING CONVERGENCE OF NUMERICAL PROCESS	I5
5	1-10	DENSITY OF LAYER	F10.3
	11-15	NUMBER OF MESH INTERVALS IN LAYER (DEFAULT IS MAXIMUM ALLOWABLE)	I5

6A,B..		SOUND SPEED PROFILE IN THIS LAYER	
	1-10	DEPTH	Flu.3
	11-20	SOUND SPEED	Flu.3
	21-30	DEPTH	Flu.3
	. . .	. . .	. . .
	71-80	SOUND SPEED	Flu.3
7		BLANK CARD	
		REPEAT CARDS 5-7 FOR EACH SEDIMENT LAYER	
8	1-10	DENSITY OF SUBSTRATE	Flu.3
9	1-10	DEPTH OF SEDIMENT/SUBSTRATE INTERFACE	Flu.3
	11-20	COMPRESSIONAL SPEED	Flu.3
	21-30	DEPTH OF SEDIMENT/SUBSTRATE INTERFACE	Flu.3
	31-40	SHEAR SPEED	Flu.3

ON OUTPUT

NEMESIS USES FILES LFOUT, LTAPE1, AND LFDIAG AS OUTPUT FILES

ON LFOUT

NEMESIS USES FILE LFOUT TO OUTPUT ALL PRINTED INFORMATION SUCH AS INPUTS AND QUANTITIES THAT WERE CALCULATED IN THE PROGRAM SUCH AS EIGENVALUES, GROUP VELOCITIES, AND ATTENUATION TERMS. THE ATTENUATION TERMS FOR EACH MODE ARE LISTED IN THE FOLLOWING ORDER:

ATTENUATION IN WATER LAYER
ATTENUATION IN FIRST SEDIMENT LAYER
. . .
ATTENUATION IN LAST SEDIMENT LAYER
ATTENUATION IN SUBSTRATE (COMPRESSIONAL)
ATTENUATION IN SUBSTRATE (SHEAR)

ON LFDIAG

NEMESIS USES LFDIAG FOR PRINTED DIAGNOSTIC MESSAGES. CAUTION - IF DIAGNOSTIC PRINT OPTION IS TURNED ON, THIS FILE CAN BE VERY LARGE. THE FOLLOWING ERROR AND DIAGNOSTIC MESSAGES ARE GENERATED BY NEMESIS:

FATAL INPUT ERRORS

ONLY 10 LAYERS ARE ALLOWED

AT LEAST TWO LAYERS MUST BE USED TO RUN NEMESIS

SOUND SPEED ARRAY OVERFLOW

ALL DEPTHS MUST BE IN INCREASING ORDER

DEPTHS AT LAYER INTERFACES MUST BE EQUAL

EACH LAYER MUST HAVE AT LEAST TWO DEPTH-SOUND SPEED POINTS

DEPTH AT AIR-WATER INTERFACE MUST BE ZERO

SOUND SPEED MINIMUM OF THE WATER AND SEDIMENT LAYERS
MUST BE LESS THAN THE COMPRESSIONAL VELOCITY

SHEAR SPEED MUST BE LESS THAN THE COMPRESSIONAL SPEED

IF THE SHEAR SPEED IS NONZERO, THE SOUND SPEED MINIMUM
MUST BE LESS THAN THE SHEAR SPEED

OPTIONS MUST BE SPECIFIED WITH A 0 OR 1

TOO MANY SPEEDS FOR SUBSTRATE

FATAL ERRORS (NUMERICAL AND PROGRAMMING)

INTEGRATION COUNT EXCEEDS MAXIMUM ALLOWABLE, MODE NO =

ALL MATCH POINTS EXHAUSTED, CONVERGENCE NOT ACHIEVED, FOR MODE NO

ERROR IN NUMROV, CALLED FROM INTGRL, IER =

ERROR IN SUBROUTINE INTRP AFTER CALL TO ICSICU

ERROR IN SUBROUTINE INTRP AFTER CALL TO ICSEVU

ERROR IN CALL TO SECANT FOR MODE NUMBER.

ERROR IN COMPUTATION OF RAYLEIGH VELOCITY

ERRORS DETECTED IN IMSL ROUTINES

*** TERMINAL ERROR, IER = FROM IMSL ROUTINE

*** WARNING WITH FIX ERROR IER = FROM IMSL ROUTINE

*** WARNING ERROR IER = FROM IMSL ROUTINE

*** UNDEFINED ERROR IER = FROM IMSL ROUTINE

DIAGNOSTIC PRINTS FOR TRACING CONVERGENCE OF NUMERICAL PROCESS
(FOR MORE DETAILED INFORMATION SEE GONZALEZ AND HAWKER, 1980)

THE CURRENT MODE NUMBER BEING COMPUTED:

MODENO =

ONE OF THE FOLLOWING IS PRINTED FOR EACH TRIAL EIGENVALUE:

FIRST ESTIMATE
SECOND ESTIMATE
SECANT ITERATE
RIGHT BOUND ESTIMATE FROM REFINE
LEFT BOUND ESTIMATE FROM REFINE
RIGHT BOUND ESTIMATE FROM ZEROIN
LEFT BOUND ESTIMATE FROM ZEROIN
BISECTION ESTIMATE

THE TRIAL EIGENVALUE, NUMBER OF ZEROS IN THE TRIAL EIGENFUNCTION, AND INTEGRATION NUMBER:

KN = NZEROS = INTEGRATION NO =

THE FIVE POINTS CENTERED AT THE MATCH POINT FOR EACH UPPER AND LOWER HALF OF TRIAL MODE:

U-UPPER U-LOWER

THE DEPTH DERIVATIVE EVALUATED AT THE MATCH POINT FOR EACH UPPER AND LOWER HALF OF TRIAL MODE:

UPPER DERV = LOWER DERV =

THE DISCONTINUITY IN THE DEPTH DERIVATIVES AT THE MATCH POINT, I.E., DISC = UPPER DERV - LOWER DERV. RATIO IS THE SCALING FACTOR THAT WAS APPLIED TO THE UPPER HALF TO FORCE CONTINUITY IN THE UPPER AND LOWER HALVES OF TRIAL MODE:

DISCONTINUITY = RATIO =

DIAGNOSTIC PRINTS FOR TRACKING DISCONTINUITY (PHI) IN FIRST DERIVATIVE OF TRIAL EIGENFUNCTIONS FOR A RANGE OF TRIAL EIGENVALUES FOR A FIXED MATCH POINT:

PHI ZEROS ZMATCH

ON LTAPE1

NEMESIS GENERATES A DISK/TAPE FILE ON LTAPE1 THAT CONTAINS ALL OF THE RELEVANT INPUT DATA TOGETHER WITH ALL OF THE EIGENVALUES, GROUP VELOCITIES, ATTENUATION TERMS, AND NORMAL MODES. NOTE - WITH THE EXCEPTION OF THE HEADER INFORMATION, ALL QUANTITIES ARE OUTPUT AS FLOATING POINT NUMBERS. LTAPE1 HAS THE FOLLOWING STRUCTURE:

LOGICAL RECORD NO	WORD NO IN RECORD	DESCRIPTION OF RECORD	NO OF WORDS PER RECORD
1	1-8	HEADER INFORMATION	8
2	1	NUMBER OF LAYERS	20
	2	MAXIMUM ALLOWABLE LAYERS	
	3	0.0	
	4	FREQUENCY IN HERTZ	
	5	COMPRESSIONAL SPEED IN SUBSTRATE	
	6	SHEAR SPEED IN SUBSTRATE	
	7	RAYLEIGH SPEED AT SUBSTRATE INTERFACE	
	8	PRESSURE RELEASE SUBSTRATE (1=YES,0=NO)	
	9	LAST MODE COMPUTED	
	10	FIRST MODE COMPUTED	
	11-20	0.0	
3	1-10	INDEX OF THE LAST MESH POINT IN EACH LAYER OF THE MODES, BEGINNING WITH LAYER 1	NO
4	1-10	INDEX OF THE LAST POINT IN EACH LAYER OF THE INPUT SOUND SPEED PROFILE	NO
5	1-10	DEPTH AT EACH LAYER INTERFACE	NO
6	1-10	MESH INCREMENT (IN METERS) FOR EACH LAYER	NO
7	1-10	DENSITY OF EACH LAYER	NO

8	1-N1	DEPTHS CORRESPONDING TO THE INPUT SOUND SPEED PROFILE	N1
9	1-N1	SOUND SPEEDS CORRESPONDING TO THE INPUT SOUND SPEED PROFILE	N1
10 - (N3+9)	1-N2	NORMAL MODES EVALUATED AT EACH MESH POINT (THERE IS ONE RECORD PER MODE)	N2
N3+10	1-N3	EIGENVALUES CORRESPONDING TO EACH MODE	N3
N3+11	1-N3	GROUP VELOCITIES OF EACH MODE	N3
N3+12		ATTENUATION TERMS PER LAYER PER MODE	N4
	1-N5	ATTENUATION TERMS FOR EACH MODE IN EACH LAYER, BEGINNING WITH LAYER 1. BOTH SHEAR AND COMPRESSIONAL ATTENUATIONS ARE COMPUTED. THEREFORE, THERE ARE AS MANY ATTENUATION TERMS FOR EACH MODE AS THERE ARE LAYERS+1	
(N5+1)-2N5		ATTENUATION TERMS FOR SECOND MODE COMPUTED	
(2N5+1)-3N5		ATTENUATION TERMS FOR THIRD MODE COMPUTED	
• • •		• • • • •	
((N3-1)*N5+1) -N3*N5		ATTENUATION TERMS FOR LAST MODE COMPUTED	

END - OF - FILE

TOTAL NUMBER OF WORDS IN FILE LTAPE1 IS

$$28 + 5*N0 + 2*N1 + (2+N2+N5)*N3$$

DEFINITIONS

N0 MAXIMUM ALLOWABLE LAYERS

N1 TOTAL NO. OF POINTS IN INPUT SOUND SPEED PROFILE. ACCESS WORD NUMBER (LAYERS-1) IN 4TH RECORD

N2 TOTAL NO. OF MESH POINTS IN MODES. ACCESS WORD NUMBER (LAYERS-1) IN 3RD RECORD

N3 TOTAL NO. OF MODES. SUBTRACT FIRST MODE COMPUTED FROM LAST MODE COMPUTED AND ADD 1

N4 N3 * NUMBER OF LAYERS

N5 NUMBER OF LAYERS + 1

REQUIRED RESIDENT ROUTINES

STANDARD FORTRAN

ABS, ALOG10, AMAX1, AMIN1, FLOAT, IABS, IFIX, MAX0, MIN0, MOD, SQRT

NONSTANDARD - THESE MUST BE WRITTEN AT EACH NEW INSTALLATION

EOF (U)

PURPOSE	FUNCTION THAT TESTS FOR AN END OF FILE CONDITION FOLLOWING A READ
FORMAL PARAMETERS	U - UNIT (FILE NAME)
VALUE RETURNED	ZERO IF NO END OF FILE IS ENCOUNTERED NONZERO OTHERWISE

IBUFOUT (U, IFRMAT, ARRAY, NPTS)

PURPOSE	FUNCTION THAT BUFFERS OUT A CONTIGUOUS BLOCK OF WORDS
FORMAL PARAMETERS	U - UNIT (FILE NAME) IFRMAT - ONE FOR BINARY FORMAT ARRAY - ADDRESS OF FIRST WORD IN BLOCK NPTS - NUMBER OF WORDS TO BE BUFFERED OUT
VALUE RETURNED	ZERO IF SUCCESSFUL NONZERO OTHERWISE

CURRENT LIMITS

VARIABLE	DESCRIPTION	LIMIT
MESHMX	MAXIMUM NUMBER OF MESH POINTS	2000
LYRMAX	MAXIMUM NUMBER OF LAYERS	10
MXINPT	MAXIMUM NUMBER OF DEPTH-SOUND SPEED PAIRS WHICH CAN BE INPUT	125
NMODMX	MAXIMUM MODE NUMBER WHICH CAN BE COMPUTED	300

ARRAY DIMENSIONS

ARRAY	ARRAY DIMENSION
AKSQR	MESHMX
DEPTH1	MESHMX
SPEED	MESHMX
U	MESHMX
AKSQRH	LYRMAX
BUFF1	LYRMAX
BUFF2	LYRMAX
BUFF3	LYRMAX
CHALF	LYRMAX
DELZ	LYRMAX
H	LYRMAX
MESH	LYRMAX
NET	LYRMAX
NPTS	LYRMAX
RHO	LYRMAX
ATTEN	LYRMAX+1
Z	MXINPT
C	MXINPT
COEF	MXINPT*3
BUFAKN	NMODMX
BUFGV	NMODMX
BUFATT	NMODMX*(LYRMAX+1)
IHEADR	80 CHARACTERS

COMPUTER RESOURCES

NEMESIS WAS PROGRAMMED ON A CONTROL DATA CORPORATION CYBER 171, UNDER THE NOS 1.3 LEVEL 485 OPERATING SYSTEM. THIS COMPUTER HAS A 60-BIT WORD WITH 10 CHARACTERS PER WORD. THE FORTRAN COMPILER IS FORTRAN FOUR EXTENDED (4.7+485) WHICH IS DESCRIBED IN CDC PUBLICATION 60497800, REVISION D. EFFORTS WERE MADE TO MAINTAIN ANSI STANDARD FORTRAN CODE. PORTIONS OF THE CODE ARE UNAVOIDABLY INSTALLATION DEPENDENT, SUCH AS THE NUMBER OF CHARACTERS PER WORD.

ON THIS MACHINE, THE LAST WORD ADDRESS (LWA) OF NEMESIS WAS 62121 OCTAL WORDS. THIS CAN BE REDUCED BY DECREASING THE SIZES OF THE ARRAYS IN THE MAIN PROGRAM AND APPROPRIATE COMMON BLOCKS, AS DESCRIBED IN THE SECTION, CURRENT LIMITS.

NEMESIS WAS RUN WITH A TYPICAL DEEP WATER PROFILE WITH TWO SEDIMENT LAYERS AND A FLUID SUBSTRATE. EIGENVALUES, EIGENFUNCTIONS, GROUP VELOCITIES, AND ATTENUATION TERMS WERE COMPUTED AND STORED ON A FILE. THE TOTAL EXECUTION TIME FOR THE 140 MODES WITH 1999 MESH POINTS PER MODE WAS 194.15 CP SECONDS (OPTIMIZED). SEE ARL-TM-80-6, CHAPTER 3, FOR FURTHER DETAILS OF THIS EXAMPLE.

III. NEMESIS: EXAMPLES

Two data sets and the corresponding printed output from NEMESIS are included in this chapter. The modeled environment is shown in Fig. 1. It consists of four layers: water, two sediment layers, and the substrate. The density in each of the four layers is 1.0, 1.5, 1.75, and 2.0 g/cm^3, respectively. The sound speeds in the sediment layers vary linearly with depth, and there is a discontinuity in sound speed at the water-sediment interface. Note that the sound speed must be specified at the top and bottom interface of each water and sediment layer, and that within the substrate the shear and compressional speeds must be constant.

The first data set does not include shear waves in the substrate; i.e., the substrate is a fluid, and thus the shear speed is zero. At 50 Hz there are 149 modes, as shown in the printed output. The five attenuation terms listed for each mode pertain to the compressional wave in the water, the sediment layers and the substrate, and the shear wave in the substrate, in that order. Because shear waves are not included, the shear wave attenuation term is identically zero for all modes. In this data set the option to suppress hidden depth calculations is not chosen. Thus, for modes with turning points high above the water-sediment interface (modes 1 to 49), the sediment attenuation terms are zero. Note that the phase velocities of the modes are bounded by the minimum sound speed in the water and the substrate compressional speed. This computation requires 194 cp sec on a Control Data Corporation CYBER 171 when NEMESIS is compiled under maximum optimization.

The second data set describes the environment in Fig. 1 with a solid substrate. The substrate compressional speed is 5000 m/sec and the shear speed is 2700 m/sec. At 50 Hz there are 282 modes with phase velocities bracketed between the minimum sound speed in the water and the shear speed. This computation requires 347 cp sec on the CYBER 171 in the optimized mode.

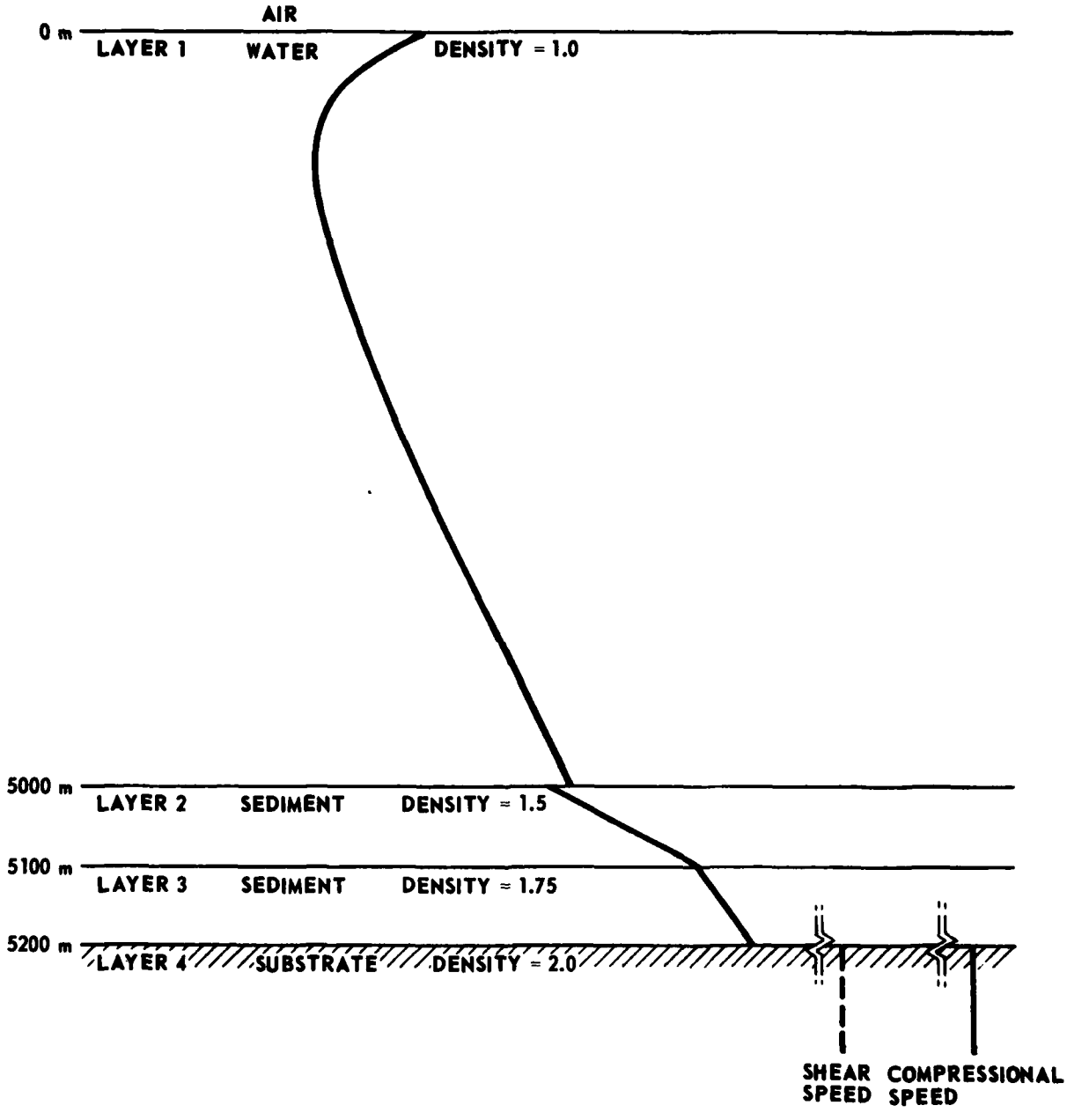


FIGURE 1
A DIAGRAMMATIC REPRESENTATION OF THE ENVIRONMENT DESCRIBED IN THE DATA SETS FOR NEMESIS

ARL:UT
AS-80-1066
SGP-GA
4-15-80

A. DATA SET (1)

The following printout constitutes the data set of the first example generated by the computer model NEMESIS, for this report.

MUNK PROFILE, C1 = 1500, Z1 = 1000, EPS = .0074, B = 1233.33
50.

1.000

0.000	1527.081	51.000	1523.539	101.000	1520.411	152.000	1517.543
202.000	1515.024	253.000	1512.728	303.000	1510.725	354.000	1508.915
404.000	1507.351	455.000	1505.952	505.000	1504.760	556.000	1503.712
606.000	1502.836	657.000	1502.085	707.000	1501.477	758.000	1500.978
808.000	1500.598	859.000	1500.314	909.000	1500.127	962.000	1500.024
1010.000	1500.001	1061.000	1500.053	1111.000	1500.170	1162.000	1500.352
1212.000	1500.587	1263.000	1500.880	1313.000	1501.216	1364.000	1501.603
1414.000	1502.024	1465.000	1502.492	1515.000	1502.985	1566.000	1503.521
1616.000	1504.076	1667.000	1504.669	1717.000	1505.276	1768.000	1505.919
1818.000	1506.570	1869.000	1507.254	1919.000	1507.943	1970.000	1508.662
2020.000	1509.383	2071.000	1510.133	2121.000	1510.880	2172.000	1511.655
2222.000	1512.426	2273.000	1513.223	2323.000	1514.013	2374.000	1514.828
2424.000	1515.635	2475.000	1516.465	2525.000	1517.296	2576.000	1518.130
2626.000	1518.963	2677.000	1519.818	2727.000	1520.561	2778.000	1521.525
2828.000	1522.377	2879.000	1523.249	2929.000	1524.108	2980.000	1524.988
3030.000	1525.853	3081.000	1526.738	3131.000	1527.606	3182.000	1528.499
3232.000	1529.374	3283.000	1530.266	3333.000	1531.147	3384.000	1532.045
3434.000	1532.926	3485.000	1533.827	3535.000	1534.712	3586.000	1535.616
3636.000	1536.503	3687.000	1537.408	3737.000	1538.297	3788.000	1539.205
3838.000	1540.095	3889.000	1541.005	3939.000	1541.897	3990.000	1542.807
4040.000	1543.700	4091.000	1544.612	4141.000	1545.506	4192.000	1546.419
4242.000	1547.314	4293.000	1548.227	4343.000	1549.123	4394.000	1550.037
4444.000	1552.934	4495.000	1551.849	4545.000	1552.746	4596.000	1553.661
4646.000	1554.558	5000.000	1560.917				

1.500

5000.000	1550.000	5100.000	1650.000

1.750

5100.000	1650.000	5200.000	1680.000

2.000

5200.000	1700.000

B. PRINTED OUTPUT (1)

The following printout is the output generated by data set (1) of NEMESIS.

NEMESIS ARL-UT NORMAL MODE MODEL
VERSION 1.2

MUNK PROFILE, C1 = 1500, Z1 = 1000, EPS = .0074, B = 1233.33

FREQUENCY (HZ)	50.000
NUMBER OF EXISTING MODES	149
FIRST MODE COMPUTED	1
LAST MODE COMPUTED	149
DEPTH (M) AT WHICH MODES ARE MATCHED	1010.000

NO OPTIONS SELECTED

GEOACOUSTIC PROFILE

LAYER	TOTAL DEPTH (M)	LOCAL DEPTH (M)	COMPRESSIONAL WAVE SPEED (M/SEC)	SHEAR WAVE SPEED (M/SEC)	RAYLEIGH WAVE SPEED (M/SEC)	DENSITY (G/CC)	SAMPLING POINTS
1	0.000	0.000	1527.061			1.000	1921
	51.000	51.000	1523.539				
	101.000	101.000	1520.411				
	152.000	152.000	1517.543				
	202.000	202.000	1515.024				
	253.000	253.000	1512.728				
	303.000	303.000	1510.725				
	354.000	354.000	1508.915				
	404.000	404.000	1507.351				
	455.000	455.000	1505.952				
	505.000	505.000	1504.760				
	556.000	556.000	1503.712				
	606.000	606.000	1502.836				
	657.000	657.000	1502.085				
	707.000	707.000	1501.477				
	758.000	758.000	1500.978				
	808.000	808.000	1500.598				
	859.000	859.000	1500.314				
	909.000	909.000	1500.127				
	960.000	960.000	1500.024				
	1010.000	1010.000	1500.001				
	1061.000	1061.000	1500.053				
	1111.000	1111.000	1500.170				
	1162.000	1162.000	1500.352				
	1212.000	1212.000	1500.587				
	1263.000	1263.000	1500.860				
	1313.000	1313.000	1501.216				
	1364.000	1364.000	1501.603				
	1414.000	1414.000	1502.024				
	1465.000	1465.000	1502.492				
	1515.000	1515.000	1502.985				
	1566.000	1566.000	1503.521				
	1616.000	1616.000	1504.076				
	1667.000	1667.000	1504.669				
	1717.000	1717.000	1505.276				
	1768.000	1768.000	1505.919				
	1818.000	1818.000	1506.570				
	1869.000	1869.000	1507.254				
	1919.000	1919.000	1507.943				
	1970.000	1970.000	1508.662				
	2020.000	2020.000	1509.383				
	2071.000	2071.000	1510.133				
	2121.000	2121.000	1510.880				
	2172.000	2172.000	1511.655				
	2222.000	2222.000	1512.426				
	2273.000	2273.000	1513.223				
	2323.000	2323.000	1514.013				

	2374.000	2374.000	1514.828				
	2424.000	2424.000	1515.635				
	2475.000	2475.000	1516.465				
	2525.000	2525.000	1517.286				
	2576.000	2576.000	1518.130				
	2626.000	2626.000	1518.963				
	2677.000	2677.000	1519.818				
	2727.000	2727.000	1520.661				
	2778.000	2778.000	1521.525				
	2828.000	2828.000	1522.377				
	2879.000	2879.000	1523.249				
	2929.000	2929.000	1524.108				
	2980.000	2980.000	1524.988				
	3030.000	3030.000	1525.853				
	3081.000	3081.000	1526.738				
	3131.000	3131.000	1527.608				
	3182.000	3182.000	1528.499				
	3232.000	3232.000	1529.374				
	3283.000	3283.000	1530.268				
	3333.000	3333.000	1531.147				
	3384.000	3384.000	1532.045				
	3434.000	3434.000	1532.926				
	3485.000	3485.000	1533.827				
	3535.000	3535.000	1534.712				
	3586.000	3586.000	1535.616				
	3636.000	3636.000	1536.503				
	3687.000	3687.000	1537.408				
	3737.000	3737.000	1538.297				
	3788.000	3788.000	1539.205				
	3838.000	3838.000	1540.095				
	3889.000	3889.000	1541.005				
	3939.000	3939.000	1541.897				
	3990.000	3990.000	1542.807				
	4040.000	4040.000	1543.700				
	4091.000	4091.000	1544.612				
	4141.000	4141.000	1545.506				
	4192.000	4192.000	1546.419				
	4242.000	4242.000	1547.314				
	4293.000	4293.000	1548.227				
	4343.000	4343.000	1549.123				
	4394.000	4394.000	1550.037				
	4444.000	4444.000	1550.934				
	4495.000	4495.000	1551.849				
	4545.000	4545.000	1552.746				
	4596.000	4596.000	1553.661				
	4646.000	4646.000	1554.558				
	5000.000	5000.000	1560.917				
2	5000.000	0.000	1550.000			1.500	39
	5100.000	100.000	1650.000				
3	5100.000	0.000	1650.000			1.750	39
	5200.000	100.000	1680.000				
4	5200.000	0.000	1700.000	0.000	2.000	2.000	

MODE CHARACTERISTICS

MODE NUMBER	WAVE NUMBER (1/M)	PHASE VELOCITY (M/SEC)	GROUP VELOCITY (M/SEC)	ATTENUATION TERMS
1	.209369849	1500.4991	1500.0009	.100016603E+01 0. 0. 0. 0.
2	.209231409	1501.4919	1500.0084	.100049429E+01 0. 0. 0. 0.
3	.209094015	1502.4785	1500.0227	.100081806E+01 0. 0. 0. 0.
4	.208957603	1503.4594	1500.0443	.100113733E+01 0. 0. 0. 0.
5	.208822191	1504.4343	1500.0725	.100145223E+01 0. 0. 0. 0.
6	.208687766	1505.4034	1500.1074	.100176282E+01 0. 0. 0. 0.
7	.208554294	1506.3668	1500.1480	.100206944E+01 0. 0. 0. 0.

8	.208421764	1507.3247	1500.1949	.100237195E+01 0. 0. 0. 0.
9	.208290160	1508.2770	1500.2476	.100267054E+01 0. 0. 0. 0.
10	.208159474	1509.2240	1500.3062	.100296520E+01 0. 0. 0. 0.
11	.208029680	1510.1656	1500.3690	.100325653E+01 0. 0. 0. 0.
12	.207900757	1511.1021	1500.4385	.100354376E+01 0. 0. 0. 0.
13	.207772716	1512.0333	1500.5118	.100382785E+01 0. 0. 0. 0.
14	.207645512	1512.9596	1500.5901	.100410843E+01 0. 0. 0. 0.
15	.207519141	1513.8809	1500.6715	.100438618E+01 0. 0. 0. 0.
16	.207393575	1514.7975	1500.7568	.100466094E+01 0. 0.

				0. 0.
17	.207268802	1515.7094	1500.8467	.100493244E+01 0. 0. 0. 0.
18	.207144803	1516.6167	1500.9353	.100520271E+01 0. 0. 0. 0.
19	.207021525	1517.5198	1501.0229	.100547180E+01 0. 0. 0. 0.
20	.206898936	1518.4190	1501.1075	.100574042E+01 0. 0. 0. 0.
21	.206776963	1519.3146	1501.1826	.100601097E+01 0. 0. 0. 0.
22	.206655527	1520.2074	1501.2477	.100628377E+01 0. 0. 0. 0.
23	.206534551	1521.0979	1501.2999	.100655999E+01 0. 0. 0. 0.
24	.206413938	1521.9867	1501.3375	.100684046E+01 0. 0. 0. 0.

25	.206293595	1522.8745	1501.3599	.100712556E+01 0. 0. 0. 0.
26	.206173442	1523.7620	1501.3723	.100741376E+01 0. 0. 0. 0.
27	.206053429	1524.6495	1501.3780	.100770413E+01 0. 0. 0. 0.
28	.205933512	1525.5374	1501.3803	.100799561E+01 0. 0. 0. 0.
29	.205813688	1526.4255	1501.3862	.100828584E+01 0. 0. 0. 0.
30	.205693961	1527.3140	1501.3962	.100857465E+01 0. 0. 0. 0.
31	.205574351	1528.2026	1501.4155	.100886027E+01 0. 0. 0. 0.
32	.205454890	1529.0912	1501.4422	.100914324E+01 0. 0. 0. 0.
33	.205335596	1529.9796	1501.4777	.100942306E+01 0. 0. 0.

				0.
34	.205216505	1530.8674	1501.5261	.100969821E+0 0. 0. 0. 0.
35	.205097665	1531.7545	1501.5867	.100996882E+0 0. 0. 0. 0.
36	.204979097	1532.6405	1501.6534	.101023695E+0 0. 0. 0. 0.
37	.204860823	1533.5254	1501.7309	.101050088E+0 0. 0. 0. 0.
38	.204742872	1534.4088	1501.8176	.101076114E+0 0. 0. 0. 0.
39	.204625265	1535.2907	1501.9117	.101101821E+0 0. 0. 0. 0.
40	.204508017	1536.1709	1502.0126	.101127232E+0 0. 0. 0. 0.
41	.204391138	1537.0493	1502.1210	.101152320E+0 0. 0. 0. 0.
42	.204274661	1537.9258	1502.2427	.101176877E+0

				0. 0. 0. 0.
43	.20415850E	1538.8001	1502.3649	.101201335E+01 0. 0. 0. 0.
44	.204042940	1539.6723	1502.4916	.101225560E+01 0. 0. 0. 0.
45	.203927701	1540.5424	1502.6258	.101249448E+01 0. 0. 0. 0.
46	.203812890	1541.4102	1502.7650	.101273078E+01 0. 0. 0. 0.
47	.203698514	1542.2757	1502.9104	.101296410E+01 0. 0. 0. 0.
48	.203584580	1543.1388	1503.0596	.101319525E+01 0. 0. 0. 0.
49	.203471085	1543.9996	1503.2120	.101342436E+01 0. 0. 0. 0.
50	.203358035	1544.8579	1503.3699	.101365072E+01 .6711712771E-18 0. 0. 0.

51	.203245433	1545.7138	1503.5302	.1Z1387535E+01 .178313358E-16 0. 0. 0.
52	.203133270	1546.5673	1503.6904	.101409908E+01 .278639986E-15 0. 0. 0.
53	.203021547	1547.4183	1503.8591	.101431903E+01 .385942629E-14 .141868622E-19 0. 0.
54	.202910280	1548.2669	1504.0322	.1Z1453655E+01 .486510197E-13 .372887306E-18 0. 0.
55	.202799455	1549.1130	1504.2025	.101475409E+01 .559769306E-12 .626755545E-17 0. 0.
56	.202689068	1549.9566	1504.3776	.101495905E+01 .586951695E-11 .733597534E-16 0. 0.
57	.202579124	1550.7978	1504.5567	.1Z1518177E+01 .559617182E-10 .756813134E-15 .209550546E-21 0.
58	.202469616	1551.6366	1504.7334	.101539438E+01 .483921345E-09 .724488793E-14 .206701293E-20 0.
59	.202360538	1552.4730	1504.9159	.1Z1560408E+01 .378664237E-08

				.5034450701E-13 .1845309281E-19 0.
60	.202251899	1553.3069	1505.1027	.1015811411E+01 .2671648281E-07 .4507700911E-12 .1484908931E-18 0.
61	.202143694	1554.1383	1505.2897	.1016017661E+01 .1692461881E-06 .3074457251E-11 .1073046961E-17 0.
62	.202035919	1554.9674	1505.4796	.1016221331E+01 .9560404551E-06 .1873839931E-10 .6928957691E-17 0.
63	.201928572	1555.7940	1505.6708	.1016420631E+01 .4815709191E-05 .1014223711E-09 .3973142861E-16 0.
64	.201821650	1556.6183	1505.8630	.1016606031E+01 .2132295641E-04 .4835852141E-09 .2006870311E-15 0.
65	.201715140	1557.4402	1506.0469	.1016748951E+01 .8224083201E-04 .2008611461E-08 .8830221731E-15 0.
66	.201608995	1558.2602	1506.1913	.1016775701E+01 .2719492181E-03 .7153591901E-08 .3331376461E-14 0.
67	.201503035	1559.0796	1506.1797	.1016562321E+01 .7543620001E-03 .2137689981E-07 .1054643281E-13 0.

68	.201396738	1559.9024	1505.7987	.101599440E+01 .171755595E-02 .524645842E-07 .274315388E-13 0.
69	.201289147	1560.7362	1504.8423	.101512304E+01 .318312431E-02 .104944714E-06 .582048921E-13 0.
70	.201179063	1561.5903	1503.2999	.101421979E+01 .488695358E-02 .174276191E-06 .102691550E-12 0.
71	.201065535	1562.4720	1501.4005	.101356461E+01 .647468536E-02 .250474437E-06 .157136109E-12 0.
72	.200948140	1563.3848	1499.3953	.101326804E+01 .775188068E-02 .326363337E-06 .218504470E-12 0.
73	.200826855	1564.3290	1497.4303	.101329289E+01 .870599482E-02 .400218382E-06 .266648816E-12 0.
74	.200701852	1565.3033	1495.5573	.101355180E+01 .940603381E-02 .473667596E-06 .363780388E-12 0.
75	.200573347	1566.3061	1493.7778	.101396704E+01 .992848771E-02 .549412534E-06 .453476843E-12 0.
76	.200441542	1567.3361	1492.0796	.101448118E+01 .103342803E-01 .630322586E-06

				.560340157E-12
				0.
77	.200306609	1568.3919	1490.4454	.101505747E+01
				.106654846E-01
				.719147400E-06
				.690002976E-12
				0.
78	.200168687	1569.4726	1488.8615	.101567135E+01
				.109510129E-01
				.818676730E-06
				.849532026E-12
				0.
79	.200027889	1570.5773	1487.3167	.101630635E+01
				.112108071E-01
				.931898270E-06
				.104795962E-11
				0.
80	.199884311	1571.7055	1485.8021	.101695138E+01
				.114587572E-01
				.106215577E-05
				.129699095E-11
				0.
81	.199738030	1572.8565	1484.3112	.101759850E+01
				.117049021E-01
				.121333649E-05
				.161198206E-11
				0.
82	.199589112	1574.0301	1482.8381	.101824223E+01
				.119565492E-01
				.139004233E-05
				.201322178E-11
				0.
83	.199437612	1575.2258	1481.3786	.101887781E+01
				.122197619E-01
				.159788461E-05
				.252783102E-11
				0.
84	.199283579	1576.4433	1479.9301	.101950065E+01
				.124999636E-01
				.184379106E-05
				.319234375E-11
				0.

85	.199127857	1577.6825	1478.4895	.122016725E+01 .128015681E-01 .213626972E-05 .425610697E-11 0.
86	.198968081	1578.9430	1477.0548	.102069410E+01 .131297892E-01 .246593245E-05 .518636955E-11 0.
87	.198806687	1580.2248	1475.6246	.102125697E+01 .134861790E-01 .290615464E-05 .667555373E-11 0.
88	.198642905	1581.5277	1474.1975	.102179162E+01 .138762471E-01 .341379251E-05 .865129359E-11 0.
89	.198476764	1582.8516	1472.7729	.102229369E+01 .143120515E-01 .403029532E-05 .112913784E-10 0.
90	.198308291	1584.1963	1471.3504	.102275732E+01 .147870011E-01 .478322029E-05 .148449865E-10 0.
91	.198137513	1585.5618	1469.9297	.102317659E+01 .153151956E-01 .570710999E-05 .196641127E-10 0.
92	.197964456	1586.9478	1468.5108	.102354448E+01 .159015238E-01 .684793064E-05 .262496315E-10 0.
93	.197789147	1588.3544	1467.0943	.102385295E+01 .165537900E-01 .826433975E-05 .353196297E-10

				0.
94	.197611612	1589.7814	1465.6809	.102409272E+01 .172808671E-01 .100330778E-04 .4791134631-10 0.
95	.197431879	1591.2287	1464.2717	.102425326E+01 .180927589I-01 .122546127E-04 .655339470E-10 0.
96	.197249979	1592.6961	1462.8680	.102432265E+01 .190206676E-01 .150609738I-04 .903989264E-10 0.
97	.197065945	1594.1834	1461.4717	.102428764E+01 .200169:97E-01 .166261482E-04 .125768702E-09 0.
98	.196879813	1595.6906	1460.0851	.102413363E+01 .211548716E-01 .231797206E-04 .176485022E-09 0.
99	.196691623	1597.2173	1458.7107	.102384623E+01 .224280907E-01 .2902449371-04 .249769866E-09 0.
100	.196501418	1598.7634	1457.3514	.102341021E+01 .238496472E-01 .365565745E-04 .3564354241-09 0.
101	.196309248	1600.3284	1456.0104	.102281333E+01 .254302137E-01 .463017646E-04 .512696418E-09 0.
102	.196115166	1601.9121	1454.6905	.102204820E+01

				.271752645E-01 .589245566E-04 .742647016E-09 0.
103	.195919230	1603.5142	1453.3940	.102111698E+01 .290808038E-01 .752750798E-04 .108312384E-06 0.
104	.195721497	1605.1342	1452.1216	.102003759E+01 .311274037E-01 .963643995E-04 .158708820E-08 0.
105	.195522024	1606.7718	1450.8713	.101885172E+01 .332727117E-01 .123503578E-03 .233274173E-08 0.
106	.195320859	1608.4266	1449.6372	.101763329E+01 .354435630E-01 .157938989E-03 .343123654E-08 0.
107	.195118033	1610.0986	1448.4073	.101649478E+01 .375324533E-01 .201011393E-03 .503639919E-08 0.
108	.194913548	1611.7877	1447.1634	.101558631E+01 .393889947E-01 .253760155E-03 .735355621E-08 0.
109	.194707370	1613.4945	1445.8814	.101508193E+01 .408537414E-01 .316777566E-03 .106460663E-07 0.
110	.194499417	1615.2196	1444.5342	.101515001E+01 .417666843E-01 .389783711E-03 .152397665E-07 0.

111	.194289566	1616.9642	1443.0975	.101591181E+01 .420160843E-01 .471604596E-03 .215303092E-07 0.
112	.194077657	1618.7297	1441.5553	.101740384E+01 .415786753E-01 .561364573E-03 .300044148E-07 0.
113	.193863519	1620.5177	1439.9050	.101956033E+01 .405177159E-01 .657103189E-03 .412914595E-07 0.
114	.193646991	1622.3297	1438.1573	.102222731E+01 .389664482E-01 .758480712E-03 .562615725E-07 0.
115	.193427945	1624.1669	1436.3331	.102520068E+01 .371808991E-01 .866361952E-03 .761866230E-07 0.
116	.193206292	1626.0302	1434.4581	.102827027E+01 .352994149E-01 .983352171E-03 .102987011E-06 0.
117	.192981992	1627.9201	1432.5580	.103125255E+01 .335116323E-01 .111394911E-02 .139610394E-06 0.
118	.192755046	1629.8368	1430.6549	.103400537E+01 .319448219E-01 .126467916E-02 .190630900E-06 0.
119	.192525488	1631.7801	1428.7671	.103642609E+01 .306856724E-01

				.144444708E-02 .263238251E-06 0.
120	.192293378	1633.7498	1426.9096	.103844083E+01 .297981160E-01 .166525970E-02 .366816656E-06 0.
121	.192058799	1635.7452	1425.0957	.103998996E+01 .292959499E-01 .194352735E-02 .526369800E-06 0.
122	.191821854	1637.7658	1423.3391	.104101325E+01 .292347568E-01 .230219905E-02 .766731775E-06 0.
123	.191582665	1639.8105	1421.6559	.104143567E+01 .296418766E-01 .277414720E-02 .114305629E-05 0.
124	.191341384	1641.8783	1420.0675	.104115321E+01 .305642091E-01 .342747070E-02 .174796701E-05 0.
125	.191098197	1643.9677	1418.6031	.104001832E+01 .320653672E-01 .427371011E-02 .274710595E-05 0.
126	.190853340	1646.0769	1417.3035	.103782595E+01 .342258759E-01 .548019371E-02 .444331929E-05 0.
127	.190607119	1648.2032	1416.2237	.103430621E+01 .371319122E-01 .718722930E-02 .739990724E-05 0.

128	.193359924	1650.3435	1415.4323	.102914431E+01 .468362012E-01 .962723700E-02 .126716174E-04 0.
129	.193112243	1652.4936	1414.9993	.102207767E+01 .452596243E-01 .131105546E-01 .222064472E-04 0.
130	.189864627	1654.6487	1414.9534	.101316496E+01 .499622372E-01 .179715961E-01 .394218882E-04 0.
131	.189617555	1656.8047	1415.1902	.100330292E+01 .540152004E-01 .243666013E-01 .696485534E-04 0.
132	.189371150	1658.9605	1415.3592	.994737137E+00 .556263524E-01 .316829492E-01 .119499024E-03 0.
133	.189124817	1661.1213	1414.8984	.990587780E+00 .531682879E-01 .392754358E-01 .194408188E-03 0.
134	.188877208	1663.2990	1413.3935	.992664990E+00 .465220804E-01 .450208402E-01 .296928460E-03 0.
135	.188626794	1665.5071	1410.9755	.999527706E+00 .376377537E-01 .485556247E-01 .431365307E-03 0.
136	.188372670	1667.7540	1408.2369	.100745887E+01 .291119963E-01 .527598644E-01

				.614601423E-03 0.
137	.188114901	1670.0392	1405.8333	.101284031E+01 .226114927E-01 .552791574E-01 .690223531E-03 0.
138	.187854397	1672.3551	1404.3049	.101298574E+01 .187676860E-01 .578580122E-01 .134679542E-02 0.
139	.187592781	1674.6674	1404.1781	.100544599E+01 .178844815E-01 .662458988E-01 .216131485E-02 0.
140	.187332432	1677.0148	1406.0389	.987592312E+00 .225368940E-01 .799318166E-01 .365567000E-02 0.
141	.187076297	1679.3109	1409.9170	.959827914E+00 .272574054E-01 .975858112E-01 .620986707E-02 0.
142	.186825894	1681.5617	1413.1647	.935928275E+00 .358656069E-01 .108970632E+00 .951822569E-02 0.
143	.186577179	1683.8033	1410.8728	.940461261E+00 .397409601E-01 .996773152E-01 .118257902E-01 0.
144	.186321993	1686.1094	1403.2262	.971421986E+00 .362231700E-01 .759356486E-01 .121149745E-01 0.

145	.186056320	1688.5170	1395.2417	.100356988E+01 .301033525E-01 .543623155E-01 .116541078E-01 0.
146	.185781564	1691.0142	1389.3634	.102466736E+01 .251653453E-01 .411578844E-01 .118697739E-01 0.
147	.185500676	1693.5742	1385.7072	.103443650E+01 .221596655E-01 .348244351E-01 .137686973E-01 0.
148	.185216616	1696.1721	1384.4528	.103257264E+01 .209765405E-01 .335194957E-01 .195480018E-01 0.
149	.184933832	1698.7658	1389.4109	.100392247E+01 .211051277E-01 .369247473E-01 .433024147E-01 0.

C. DATA SET (2)

The following printout constitutes the data set for the second example generated by NEMESIS.

MUNK PROFILE, C1 = 1500, Z1 = 1000, EPS = .0074, B = 1233.33
50.

1.000							
0.000	1527.081	51.000	1523.539	101.000	1520.411	152.000	1517.543
202.000	1515.024	253.000	1512.728	303.000	1510.725	354.000	1508.915
404.000	1507.351	455.000	1505.952	505.000	1504.760	556.000	1503.712
606.000	1502.836	657.000	1502.085	707.000	1501.477	758.000	1500.978
808.000	1500.598	859.000	1500.314	909.000	1500.127	960.000	1500.024
1010.000	1500.001	1061.000	1500.053	1111.000	1500.170	1162.000	1500.352
1212.000	1500.587	1263.000	1500.880	1313.000	1501.216	1364.000	1501.623
1414.000	1502.024	1465.000	1502.492	1515.000	1502.985	1566.000	1503.521
1616.000	1504.076	1667.000	1504.669	1717.000	1505.276	1768.000	1505.919
1818.000	1506.570	1869.000	1507.254	1919.000	1507.943	1970.000	1508.662
2020.000	1509.383	2071.000	1510.133	2121.000	1510.880	2172.000	1511.655
2222.000	1512.426	2273.000	1513.223	2323.000	1514.013	2374.000	1514.828
2424.000	1515.635	2475.000	1516.465	2525.000	1517.286	2576.000	1518.130
2626.000	1518.963	2677.000	1519.816	2727.000	1520.661	2778.000	1521.525
2828.000	1522.377	2879.000	1523.249	2929.000	1524.108	2980.000	1524.986
3030.000	1525.853	3081.000	1526.738	3131.000	1527.606	3182.000	1528.499
3232.000	1529.374	3283.000	1530.268	3333.000	1531.147	3384.000	1532.045
3434.000	1532.926	3485.000	1533.827	3535.000	1534.712	3586.000	1535.616
3636.000	1536.503	3687.000	1537.408	3737.000	1538.297	3788.000	1539.205
3838.000	1540.095	3889.000	1541.205	3939.000	1541.897	3990.000	1542.807
4040.000	1543.700	4091.000	1544.612	4141.000	1545.506	4192.000	1546.419
4242.000	1547.314	4293.000	1548.227	4343.000	1549.123	4394.000	1550.037
4444.000	1550.934	4495.000	1551.849	4545.000	1552.746	4596.000	1553.661
4646.000	1554.558	5000.000	1560.917				
1.500							
5000.000	1550.000	5100.000	1650.000				
1.750							
5100.000	1650.000	5200.000	1680.000				
2.000							
5200.000	5000.000	5200.000	2700.000				

D. PRINTED OUTPUT (2)

The following printout is the output of data set (2) from NEMESIS.

NEMESIS ARL-UT NORMAL MODE MODEL
VERSION 1.2

MUNK PROFILE, C1 = 1500, Z1 = 1000, EPS = .0074, B = 1233.33

FREQUENCY (HZ)	50.000
NUMBER OF EXISTING MODES	282
FIRST MODE COMPUTED	1
LAST MODE COMPUTED	262
DEPTH (M) AT WHICH MODES ARE MATCHED	1010.000

NO OPTIONS SELECTED

GEOACOUSTIC PROFILE

LAYER	TOTAL DEPTH (M)	LOCAL DEPTH (M)	COMPRESSIONAL WAVE SPEED (M/SEC)	SHEAR WAVE SPEED (M/SEC)	RAYLEIGH WAVE SPEED (M/SEC)	DENSITY (G/CC)	SAMPLING POINTS
1	0.000	0.000	1527.061			1.000	1921
	51.000	51.000	1523.539				
	101.000	101.000	1520.411				
	152.000	152.000	1517.543				
	202.000	202.000	1515.024				
	253.000	253.000	1512.728				
	303.000	303.000	1510.725				
	354.000	354.000	1508.915				
	404.000	404.000	1507.351				
	455.000	455.000	1505.952				
	505.000	505.000	1504.760				
	556.000	556.000	1503.712				
	606.000	606.000	1502.836				
	657.000	657.000	1502.085				
	707.000	707.000	1501.477				
	758.000	758.000	1500.978				
	808.000	808.000	1500.598				
	859.000	859.000	1500.314				
	909.000	909.000	1500.127				
	960.000	960.000	1500.024				
	1010.000	1010.000	1500.001				
	1061.000	1061.000	1500.053				
	1111.000	1111.000	1500.170				
	1162.000	1162.000	1500.352				
	1212.000	1212.000	1500.587				
	1263.000	1263.000	1500.880				
	1313.000	1313.000	1501.216				
	1364.000	1364.000	1501.603				
	1414.000	1414.000	1502.024				
	1465.000	1465.000	1502.492				
	1515.000	1515.000	1502.985				
	1566.000	1566.000	1503.521				
	1616.000	1616.000	1504.076				
	1667.000	1667.000	1504.669				
	1717.000	1717.000	1505.276				
	1768.000	1768.000	1505.919				
	1818.000	1818.000	1506.570				
	1869.000	1869.000	1507.254				
	1919.000	1919.000	1507.943				
	1970.000	1970.000	1508.662				
	2020.000	2020.000	1509.383				
	2071.000	2071.000	1510.133				
	2121.000	2121.000	1510.880				
	2172.000	2172.000	1511.655				
	2222.000	2222.000	1512.426				
	2273.000	2273.000	1513.223				
	2323.000	2323.000	1514.013				

	2374.000	2374.000	1514.828				
	2424.000	2424.000	1515.635				
	2475.000	2475.000	1516.465				
	2525.000	2525.000	1517.286				
	2576.000	2576.000	1518.130				
	2626.000	2626.000	1518.963				
	2677.000	2677.000	1519.818				
	2727.000	2727.000	1520.661				
	2778.000	2778.000	1521.525				
	2828.000	2828.000	1522.377				
	2879.000	2879.000	1523.249				
	2929.000	2929.000	1524.108				
	2980.000	2980.000	1524.988				
	3030.000	3030.000	1525.853				
	3081.000	3081.000	1526.738				
	3131.000	3131.000	1527.608				
	3182.000	3182.000	1528.499				
	3232.000	3232.000	1529.374				
	3283.000	3283.000	1530.268				
	3333.000	3333.000	1531.147				
	3384.000	3384.000	1532.045				
	3434.000	3434.000	1532.926				
	3485.000	3485.000	1533.827				
	3535.000	3535.000	1534.712				
	3586.000	3586.000	1535.616				
	3636.000	3636.000	1536.503				
	3687.000	3687.000	1537.408				
	3737.000	3737.000	1538.297				
	3788.000	3788.000	1539.205				
	3838.000	3838.000	1540.095				
	3889.000	3889.000	1541.005				
	3939.000	3939.000	1541.897				
	3990.000	3990.000	1542.807				
	4040.000	4040.000	1543.700				
	4091.000	4091.000	1544.612				
	4141.000	4141.000	1545.506				
	4192.000	4192.000	1546.419				
	4242.000	4242.000	1547.314				
	4293.000	4293.000	1548.227				
	4343.000	4343.000	1549.123				
	4394.000	4394.000	1550.037				
	4444.000	4444.000	1550.934				
	4495.000	4495.000	1551.849				
	4545.000	4545.000	1552.746				
	4596.000	4596.000	1553.661				
	4646.000	4646.000	1554.558				
	5000.000	5000.000	1560.917				
2	5000.000	0.000	1550.000			1.500	39
	5100.000	100.000	1650.000				
3	5100.000	0.000	1650.000			1.750	39
	5200.000	100.000	1680.000				
4	5200.000	0.000	5000.000	2700.000	2501.555	2.000	

MODE CHARACTERISTICS

MODE NUMBER	WAVE NUMBER (1/M)	PHASE VELOCITY (M/SEC)	GROUP VELOCITY (M/SEC)	ATTENUATION TERMS
1	.209369849	1500.4991	1500.0009	.100c166031+01 0. 0. 0. 0.
2	.209231409	1501.4919	1500.0284	.100049429E+01 0. 0. 0. 0.
3	.209094015	1502.4785	1500.0227	.100081806E+01 0. 0. 0. 0.
4	.208957603	1503.4594	1500.0443	.100113733E+01 0. 0. 0. 0.
5	.208822191	1504.4343	1500.0725	.100145223E+01 0. 0. 0. 0.
6	.208687766	1505.4034	1500.1074	.100176282E+01 0. 0. 0. 0.
7	.208554294	1506.3668	1500.148v	.100206944E+01 0. 0. 0. 0.

8	.208421764	1507.3247	1500.1949	.100237195E+01 0. 0. 0. 0.
9	.208290160	1508.2770	1500.2476	.100267054E+01 0. 0. 0. 0.
10	.208159474	1509.2240	1500.3062	.100296520E+01 0. 0. 0. 0.
11	.208029680	1510.1656	1500.3690	.100325653E+01 0. 0. 0. 0.
12	.207900757	1511.1021	1500.4385	.100354378E-01 0. 0. 0. 0.
13	.207772716	1512.0333	1500.5118	.100382785E+01 0. 0. 0. 0.
14	.207645512	1512.9596	1500.5901	.100410843E+01 0. 0. 0. 0.
15	.207519141	1513.8809	1500.6715	.100438618E+01 0. 0. 0. 0.
16	.207393575	1514.7975	1500.7568	.100466094E+01 0. 0.

				0. 0.
17	.207268802	1515.7094	1500.8467	.100493244E+01 0. 0. 0. 0.
18	.207144803	1516.6167	1500.9353	.122520271E+21 0. 0. 0. 0.
19	.207021525	1517.5198	1501.0229	.122547190E+21 0. 0. 0. 0.
20	.206898936	1518.4190	1501.1095	.100574042E+01 0. 0. 0. 0.
21	.206776963	1519.3146	1501.1926	.100601097E+01 0. 0. 0. 0.
22	.206655527	1520.2074	1501.2477	.122628377E+01 0. 0. 0. 0.
23	.206534551	1521.0979	1501.2999	.100655999E+01 0. 0. 0. 0.
24	.206413936	1521.9867	1501.3375	.100684046E+01 0. 0. 0. 0.

25	.206293595	1522.8745	1501.3599	.100712556E+01 0. 0. 0. 0.
26	.206173442	1523.7620	1501.3723	.100741378E+01 0. 0. 0. 0.
27	.206053429	1524.6495	1501.3780	.100770413E+01 0. 0. 0. 0.
28	.205933512	1525.5374	1501.3803	.100799561E+01 0. 0. 0. 0.
29	.205813688	1526.4255	1501.3862	.100828564E+01 0. 0. 0. 0.
30	.205693961	1527.3140	1501.3962	.100857465E+01 0. 0. 0. 0.
31	.205574351	1528.2026	1501.4155	.100886027E+01 0. 0. 0. 0.
32	.205454690	1529.0912	1501.4422	.100914324E+01 0. 0. 0. 0.
33	.205335596	1529.9796	1501.4777	.100942306E+01 0. 0. 0.

				0.
34	.205216505	1530.8674	1501.5261	.100969821E+01 0. 0. 0. 0.
35	.205097665	1531.7545	1501.5867	.100996882E+01 0. 0. 0. 0.
36	.204979097	1532.6405	1501.6534	.101023695E+01 0. 0. 0. 0.
37	.204860823	1533.5254	1501.7309	.101050089E+01 0. 0. 0. 0.
38	.204742872	1534.4088	1501.8176	.101076114E+01 0. 0. 0. 0.
39	.204625265	1535.2907	1501.9117	.101101821E+01 0. 0. 0. 0.
40	.204508017	1536.1709	1502.0126	.101127232E+01 0. 0. 0. 0.
41	.204391138	1537.0493	1502.1210	.101152320E+01 0. 0. 0. 0.
42	.204274661	1537.9258	1502.2427	.101176877E+01

				0. 0. 0. 0.
43	.204158598	1538.6001	1502.3649	.101201335E-01 0. 0. 0. 0.
44	.204042940	1539.6723	1502.4916	.101225560E+01 0. 0. 0. 0.
45	.203927701	1540.5424	1502.6258	.101249448E+01 0. 0. 0. 0.
46	.203812890	1541.4102	1502.7650	.101273076E+01 0. 0. 0. 0.
47	.203698514	1542.2757	1502.9104	.101296410E+01 0. 0. 0. 0.
48	.203584580	1543.1388	1503.0596	.101319525E+01 0. 0. 0. 0.
49	.203471085	1543.9996	1503.2120	.101342436E+01 0. 0. 0. 0.
50	.203358035	1544.8579	1503.3699	.101365072E+01 .6711171277E-16 0. 0. 0.

51	.203245433	1545.7138	1503.5302	.101387535E+01 .178313358E-16 0. 0. 0.
52	.203133270	1546.5673	1503.6904	.101409906E+01 .278639986E-15 0. 0. 0.
53	.203021547	1547.4183	1503.8591	.101431923E+01 .385942629E-14 .141868622E-19 0. 0.
54	.202910280	1548.2669	1504.0322	.101453655E+01 .486512197E-13 .372687306E-18 0. 0.
55	.202799455	1549.1130	1504.2025	.101475409E+01 .559769306E-12 .628755545E-17 0. 0.
56	.202689068	1549.9566	1504.3776	.101496925E+01 .586951695E-11 .733597534E-16 0. 0.
57	.202579124	1550.7978	1504.5567	.101518177E+01 .559617182E-10 .756874851E-15 .465975273E-20 .528341169E-20
58	.202469616	1551.6366	1504.7334	.101539438E+01 .463921346E-09 .704550649E-14 .471102506E-19 .534429446E-19
59	.202360538	1552.4730	1504.9159	.101560408E+01 .376664237E-08

				.593501193E-13 .431216473E-18 .469433057E-18
60	.202251899	1553.3069	1505.1027	.101581141E+01 .267164828E-07 .450816024E-12 .356085785E-17 .404366496E-17
61	.202143694	1554.1383	1505.2897	.101601766E+01 .169246168E-06 .307479486E-11 .264164170E-16 .300134970E-16
62	.202035919	1554.9674	1505.4796	.101622133E+01 .958040456E-06 .187406181E-10 .175216504E-15 .199177122E-15
63	.201928572	1555.7940	1505.6708	.101642063E+01 .481570921E-05 .101435324E-09 .103265256E-14 .117446481E-14
64	.201821650	1556.6183	1505.8630	.101662623E+01 .213229565E-04 .463651857E-09 .536443156E-14 .610422358E-14
65	.201715140	1557.4402	1506.0469	.101674895E+01 .822408325E-04 .200691028E-08 .242908985E-13 .276548214E-13
66	.201608995	1558.2602	1506.1913	.101677570E+01 .271949220E-03 .715474130E-08 .943763823E-13 .107500595E-12
67	.201503035	1559.0796	1506.1797	.101656232E+01 .754362002E-03 .213826117E-07 .307927079E-12 .350926183E-12

68	.201396738	1559.9024	1505.7967	.101599440E+01 .171755596-02 .524744422E-07 .826251726E-12 .942110374E-12
69	.201289147	1560.7362	1504.8423	.101512304E+01 .318312435E-02 .124966082E-06 .181095645E-11 .206596094E-11
70	.201179063	1561.5903	1503.2999	.101421979E+01 .488695365E-02 .174314758E-06 .330624690E-11 .377380784E-11
71	.201065535	1562.4720	1501.4205	.101356461E+01 .647468547E-02 .250534903E-06 .524666259E-11 .599191684E-11
72	.200948140	1563.3848	1499.3953	.101326804E+01 .775186283E-02 .326449635E-06 .758515941E-11 .865750651E-11
73	.200826855	1564.3290	1497.4303	.101329289E+01 .870599499E-02 .400334602E-06 .103737586E-10 .118609975E-10
74	.200701852	1565.3033	1495.5573	.101355160E+01 .942603407E-02 .473819841E-06 .137646960E-10 .157476518E-10
75	.200573347	1566.3061	1493.7778	.101396704E+01 .992848800E-02 .549626521E-06 .179954106E-10 .206007548E-10
76	.200441542	1567.3361	1492.0796	.101449119E+01 .103342806E-01 .630573263E-06

				.233973119E-10
				.268020030E-10
77	.200306609	1568.3919	1490.4454	.121505747E+01
				.106654851E-01
				.719467742E-06
				.304234793E-10
				.348736573E-10
78	.200168687	1569.4726	1488.8615	.121567135E+01
				.109510135E-01
				.819087165E-06
				.397650932E-10
				.455436061E-10
79	.200027889	1570.5773	1487.3167	.121630635E+01
				.112108076E-01
				.932426762E-06
				.521358843E-10
				.598441023E-10
80	.199884311	1571.7055	1485.8021	.121695138E+01
				.114567582E-01
				.106284083E-05
				.690004452E-10
				.792503154E-10
81	.199738030	1572.8565	1484.3112	.121759652E+01
				.117049032E-01
				.121423163E-05
				.921737595E-10
				.105953498E-09
82	.199589112	1574.0301	1482.8381	.121824223E+01
				.119565506E-01
				.139122264E-05
				.124431934E-09
				.143140179E-09
83	.199437612	1575.2256	1481.3786	.121887781E+01
				.122197637E-01
				.159945681E-05
				.169958278E-09
				.195659213E-09
84	.199283579	1576.4433	1479.9301	.121952064E+01
				.124999659E-01
				.184590895E-05
				.235168085E-09
				.270938777E-09

85	.199127657	1577.6825	1478.4895	.102210725E+0 .128015712E-0 .213915818E-0 .330071564E-0 .380576692E-0
86	.198968081	1578.9430	1477.0548	.102069409E+0 .131287932E-0 .246992404E-0 .472631171E-0 .543078389E-0
87	.198806687	1580.2248	1475.6246	.102125696E+0 .134861846E-0 .251176274E-0 .582924250E-0 .786694065E-0
88	.198642905	1581.5277	1474.1975	.102179182E+0 .136782548E-0 .342179765E-0 .101068569E-0 .116818815E-0
89	.198476764	1582.8516	1472.7729	.102229367E+0 .143100623E-0 .424195036E-0 .152961224E-0 .176947775E-0
90	.198308291	1584.1963	1471.3504	.102275726E+0 .147870165E-0 .480037458E-0 .237554154E-0 .275042553E-0
91	.198137513	1585.5618	1469.9297	.102317653E+0 .153152179E-0 .573364503E-0 .380310312E-0 .440712432E-0
92	.197964456	1586.9478	1468.5108	.102354439E+0 .159015568E-0 .688982930E-0 .631565799E-0 .732524535E-0
93	.197789147	1588.3544	1467.0944	.102385281E+0 .165538404E-0 .633322144E-0 .149770005E-0

				.1274324601-07
94	.197611612	1589.7814	1465.6810	.1224092491+01 .1728094631-01 .1015247361-04 .2023953471-07 .2351777061-07
95	.197431879	1591.2287	1464.2717	.1024252651+01 .1809288891-01 .1247739231-04 .4046815501-07 .4706680451-07
96	.197249979	1592.6961	1462.8681	.1024321841+01 .1900089451-01 .1552579311-04 .5129200421-07 .1662786831-06
97	.197065946	1594.1834	1461.4720	.1024285711+01 .2001738551-01 .1980279941-04 .2526499921-06 .2944089961-06
98	.196879814	1595.6906	1460.0861	.1024126991+01 .2115588961-01 .2773960011-04 .1085553741-05 .1266217231-05
99	.196691630	1597.2173	1458.7316	.1023685141+01 .2243210251-01 .1508441911-03 .3275027331-04 .3823970011-04
100	.196640695	1597.6310	1599.5306	.2069164681-03 .2629872491-04 .8090143731+00 .2255932471+00 .2634700871+00
101	.196501414	1598.7634	1457.3538	.1223389211+01 .2384531971-01 .5595798541-04 .6530365651-05 .7057408851-05
102	.196309246	1600.3284	1456.0106	.1022810391+01

				.254278849E-01 .502661359E-04 .148058182E-05 .173221670E-05
103	.196115164	1601.9122	1454.6904	.102204762E+01 .271732619E-01 .606623313E-04 .822841089E-06 .963686894E-06
104	.195919228	1603.5142	1453.3937	.102111765E+01 .282767911E-01 .762028982E-04 .613179770E-06 .718692807E-06
105	.195721494	1605.1342	1452.1212	.102003901E+01 .311252235E-01 .966621573E-04 .532551724E-06 .625029540E-06
106	.195522021	1606.7718	1450.8708	.101885385E+01 .332702561E-01 .123607390E-03 .507887788E-06 .596726212E-06
107	.195320856	1608.4266	1449.6365	.101763621E+01 .354407474E-01 .157675188E-03 .515121939E-06 .605667049E-06
108	.195118029	1610.0986	1448.4064	.101649860E+01 .375272171E-01 .200317095E-03 .544561427E-06 .641222693E-06
109	.194913543	1611.7876	1447.1623	.101559118E+01 .393853125E-01 .252544734E-03 .591586577E-06 .697375563E-06
110	.194707363	1613.4945	1445.8799	.101508799E+01 .406496357E-01 .314845566E-03 .653399394E-06 .771116000E-06

111	.194499409	1615.2196	1444.5324	.1.1515739E+01 .417625306E-01 .386955703E-03 .727748766E-06 .659847566E-06
112	.194289556	1616.9642	1443.2953	.1015920651+01 .42013399EE-01 .467837326E-03 .812591685E-06 .961209747E-06
113	.194077645	1618.7298	1441.5526	.101741433E+01 .415738824E-01 .555968427E-03 .986336213E-06 .107336687E-05
114	.193863504	1620.5178	1439.9018	.1019572771+01 .405128863E-01 .6499323921-03 .1208436761-05 .119571665E-05
115	.193646974	1622.3298	1438.1534	.1022242191+01 .389815622E-01 .749110615E-03 .112003918E-05 .132966417E-05
116	.193427923	1624.1671	1436.3284	.1025218751+01 .371757977E-01 .854247769E-03 .1244471291-05 .1479215241-05
117	.193206266	1626.0304	1434.4525	.1028292661+01 .352937746E-01 .967763097E-03 .138754642E-05 .165135607E-05
118	.192981961	1627.9204	1432.5512	.1031280921+01 .335049340E-01 .1093868461-02 .155785373E-05 .185641811E-05
119	.192755008	1629.8371	1430.6460	.103404210E+01 .319363052E-01

				.123865417E-02 .176726243E-05 .210872672E-05
120	.192525440	1631.7805	1428.7557	.103647465E+01 .306742426E-01 .141035771E-02 .203209455E-05 .242791130E-05
121	.192293318	1633.7503	1426.8947	.103850634E+01 .297741638E-01 .161995307E-02 .237481528E-05 .284120528E-05
122	.192058722	1635.7459	1425.0758	.104008012E+01 .292731624E-01 .188222359E-02 .282737236E-05 .338726272E-05
123	.191821752	1637.7666	1423.3117	.104113991E+01 .292015585E-01 .221752157E-02 .343614077E-05 .412229438E-05
124	.191582529	1639.8117	1421.6173	.104161743E+01 .295928036E-01 .265435652E-02 .426999929E-05 .512987679E-05
125	.191341197	1641.8799	1420.0118	.104141983E+01 .304907758E-01 .323365437E-02 .543321716E-05 .653666017E-05
126	.191097933	1643.9706	1418.5206	.104041820E+01 .319543657E-01 .401453204E-02 .726859156E-05 .853743628E-05
127	.190852960	1646.0801	1417.1782	.103843870E+01 .340571874E-01 .508272716E-02 .947649953E-05 .114343270E-04

128	.190606555	1648.2081	1416.0287	.103526284E+01 .368762422E-01 .656079943E-02 .129882025E-04 .155947616E-04
129	.190359068	1650.3509	1415.1236	.103065608E+01 .424564357E-01 .861626864E-02 .182000256E-04 .220255639E-04
130	.190110917	1652.5051	1414.5077	.102446544E+01 .447256624E-01 .114542451E-01 .259328225E-04 .314310954E-04
131	.189862555	1654.6668	1414.1816	.101685196E+01 .493327484E-01 .152619837E-01 .371926828E-04 .451442822E-04
132	.189614344	1656.8328	1414.0314	.100668629E+01 .534331689E-01 .200561831E-01 .528035407E-04 .641939005E-04
133	.189366325	1659.0028	1413.7553	.100187951E+01 .556345782E-01 .254368792E-01 .726111405E-04 .884095656E-04
134	.189117952	1661.1816	1412.9056	.996967556E+00 .545173367E-01 .324680405E-01 .946259002E-04 .115392076E-03
135	.188868054	1663.3796	1411.1448	.100153150E+01 .497269152E-01 .340642182E-01 .115521903E-03 .141093657E-03
136	.188615254	1665.6090	1408.5225	.100877831E+01 .425224280E-01 .357489155E-01

				.1328997841E-03 .1625764511E-03
137	.188358556	1667.8789	1405.4276	.1018126651E+01 .3491112102E-01 .5594760188E-01 .1470916481E-03 .1822293981E-03
138	.188097632	1670.1926	1402.2928	.1027321192E+01 .2839594862E-01 .3554224182E-01 .1666945282E-03 .1972235421E-03
139	.187832708	1672.5482	1399.4233	.1033927532E+01 .2358620292E-01 .3533336312E-01 .1771557022E-03 .2177951752E-03
140	.187564321	1674.9415	1396.9203	.1038516522E+01 .2051431872E-01 .3589184252E-01 .2021261242E-03 .2464600142E-03
141	.187293158	1677.3665	1394.8562	.1039527832E+01 .1922998872E-01 .3761532262E-01 .2337241292E-03 .2863422642E-03
142	.187020010	1679.8163	1393.3364	.1037623432E+01 .1922527952E-01 .4084655612E-01 .2831460762E-03 .3499352532E-03
143	.186745787	1682.2830	1392.4199	.1032166912E+01 .2056844822E-01 .4592334392E-01 .3549255082E-03 .4394350292E-03
144	.186471531	1684.7573	1392.1587	.1022953872E+01 .2354633372E-01 .5299726782E-01 .4553902922E-03 .5648414682E-03

145	.186198271	1687.2298	1392.4215	.101267406E+01 .279950258E-01 .612550366E-01 .584163119E-03 .725904106E-03
146	.185926540	1689.6956	1392.6206	.999441648E+00 .329612687E-01 .680837782E-01 .720923809E-03 .897444510E-03
147	.185655537	1692.1621	1391.6777	.994843211E+00 .365349022E-01 .701836611E-01 .816550632E-03 .122087023E-02
148	.185382807	1694.6516	1386.8097	.100136071E+01 .369667157E-01 .651779968E-01 .833522039E-03 .104139762E-02
149	.185105445	1697.1908	1384.4102	.101647976E+01 .344468667E-01 .552471432E-01 .770903862E-03 .965005945E-03
150	.184821779	1699.7957	1379.5635	.103383861E+01 .306919364E-01 .445612352E-01 .674730684E-03 .846260651E-03
151	.184531694	1702.4678	1375.0378	.104900065E+01 .271847130E-01 .357215142E-01 .563017535E-03 .732696558E-03
152	.184235897	1705.2012	1371.0694	.106063693E+01 .245432658E-01 .293198351E-01 .511790990E-03 .644506429E-03
153	.183935266	1707.9882	1367.6216	.106920350E+01 .228447266E-01 .250300126E-01 .463273029E-03

				.584634861E-0
154	.183630577	1710.8222	1364.5920	.107472820E+0 .219863715E-0 .223671622E-0 .435090967E-0 .550249695E-0
155	.183322471	1713.6975	1361.8925	.107834422E+0 .216531043E-0 .209490899E-0 .424596411E-0 .538152622E-0
156	.183011483	1716.6096	1359.4664	.108019370E+0 .223665418E-0 .205345523E-0 .430222287E-0 .546471150E-0
157	.182698090	1719.5542	1357.2854	.108044993E+0 .234872624E-0 .209994462E-0 .451573757E-0 .574914628E-0
158	.182382758	1722.5272	1355.3414	.107917159E+0 .251982930E-0 .223225051E-0 .489408205E-0 .624510278E-0
159	.182065957	1725.5245	1353.6344	.107636140E+0 .274725128E-0 .244446309E-0 .544679202E-0 .696926509E-0
160	.181748162	1728.5416	1352.1531	.107219384E+0 .302158296E-0 .274074544E-0 .615466502E-0 .792879768E-0
161	.181429798	1731.5748	1350.8436	.106721909E-0 .331805869E-0 .312521273E-0 .707765141E-0 .909508891E-0
162	.181111118	1734.6216	1349.5687	.106180586E-0

				.358780531E-01 .349850254E-01 .844410207E-03 .103616984E-02
163	.180792003	1737.6834	1348.0912	.105511531E+01 .375921077E-01 .384804443E-01 .892154643E-03 .115196334E-02
164	.180471807	1740.7664	1346.1352	.105767683E+01 .376329144E-01 .406422613E-01 .950352368E-03 .123009921E-02
165	.180149402	1743.8818	1343.5341	.106142234E+01 .357718737E-01 .408601813E-01 .964395140E-03 .125136261E-02
166	.179823530	1747.0420	1340.3457	.106880356E+01 .324615242E-01 .392113451E-01 .935293144E-03 .121665896E-02
167	.179493229	1750.2569	1336.8046	.107817597E+01 .285580810E-01 .363725313E-01 .878159792E-03 .114527962E-02
168	.179158052	1753.5314	1333.1700	.107801294E+01 .246390215E-01 .331629721E-01 .811907852E-03 .106166503E-02
169	.178818012	1756.8659	1329.6225	.109656981E+01 .217517293E-01 .301867117E-01 .750387975E-03 .984521317E-03
170	.178473391	1760.2583	1326.2409	.110393353E+01 .194461586E-01 .277593934E-01 .702991673E-03 .924262774E-03

171	.178124590	1763.7052	1323.0557	.110978670E+01 .179091665E-01 .259948330E-01 .671533175E-03 .885386572E-03
172	.177772037	1767.2029	1320.0629	.111417677E+01 .178739717E-01 .249095351E-01 .657650933E-03 .869571568E-03
173	.177416156	1770.7478	1317.2554	.111717525E+01 .168796566E-01 .244928619E-01 .661984943E-03 .877862582E-03
174	.177057367	1774.3360	1314.6318	.111881061E+01 .172961591E-01 .247434783E-01 .685600829E-03 .911881464E-03
175	.176696108	1777.9637	1312.2003	.111904480E+01 .183310963E-01 .256835530E-01 .730402587E-03 .974405884E-03
176	.176332853	1781.6264	1309.9784	.111777955E+01 .200254407E-01 .273567837E-01 .799127903E-03 .106936024E-02
177	.175968127	1785.3191	1307.9870	.111490113E+01 .224344219E-01 .298060720E-01 .894718616E-03 .120099626E-02
178	.175602503	1789.0364	1306.2337	.111039596E+01 .255792133E-01 .330157313E-01 .101847578E-02 .137142160E-02
179	.175236535	1792.7726	1304.6791	.110458337E+01 .293480273E-01

				.367963062E-01 .116615164E-02 .157526665E-02
180	.174870598	1796.5242	1303.1863	.109844925E+01 .333460000E-01 .406381206E-01 .132206051E-02 .179160528E-02
181	.174504615	1800.2920	1301.4871	.109385005E+01 .366036885E-01 .436135468E-01 .145509532E-02 .197628141E-02
182	.174137783	1804.0844	1299.2442	.109304709E+01 .367313344E-01 .446507539E-01 .152586130E-02 .206129816E-02
183	.173768604	1807.9173	1296.2412	.109740793E+01 .384867898E-01 .431643625E-01 .150876971E-02 .206484760E-02
184	.173395354	1811.8090	1292.5447	.110634597E+01 .362481845E-01 .395353770E-01 .141134284E-02 .193808980E-02
185	.173016725	1815.7740	1286.4449	.111777986E+01 .328625047E-01 .348339239E-01 .126786715E-02 .174714067E-02
186	.172632133	1819.8192	1284.2517	.112954761E+01 .292541071E-01 .301149912E-01 .111554787E-02 .154274773E-02
187	.172241609	1823.9453	1280.1620	.114029980E+01 .260248666E-01 .260058659E-01 .978504600E-03 .135019687E-02

188	.171845517	1828.1493	1276.2546	.114951707E+01 .234455959E-01 .227238681E-01 .866717183E-03 .122756508E-02
189	.171444330	1832.4273	1272.5374	.115716957E+01 .214915364E-01 .202549284E-01 .781526415E-03 .116307326E-02
190	.171038516	1836.7750	1268.9902	.116342098E+01 .201674421E-01 .184998755E-01 .720661622E-03 .101195159E-02
191	.170628492	1841.1888	1265.5873	.116846659E+01 .193784942E-01 .173513612E-01 .681199872E-03 .960370748E-03
192	.170214626	1845.6655	1262.3273	.117246614E+01 .192609316E-01 .167243378E-01 .660610716E-03 .935179134E-03
193	.169797249	1850.2023	1259.1366	.117552359E+01 .191718942E-01 .165640495E-01 .657379016E-03 .934514594E-03
194	.169376676	1854.7965	1256.0693	.117768612E+01 .196903231E-01 .168459862E-01 .670988037E-03 .957947767E-03
195	.168953221	1859.4453	1253.1067	.117895021E+01 .206139627E-01 .175728007E-01 .701995218E-03 .100644626E-02
196	.168527217	1864.1456	1250.2560	.117927296E+01 .219530695E-01 .187696645E-01

				.751405263E-03
				.108223092E-02
197	.168099024	1868.8940	1247.5277	.117859287E+01
				.237222985E-01
				.204756580E-01
				.821383720E-03
				.115837139E-02
198	.167669038	1873.6868	1244.9309	.117687049E+01
				.259095717E-01
				.227276255E-01
				.913613861E-03
				.132788948E-02
199	.167237667	1878.5198	1242.4630	.117416391E+01
				.264614225E-01
				.255243222E-01
				.102847813E-02
				.150182398E-02
200	.166825280	1883.3892	1240.0945	.117074944E+01
				.312108984E-01
				.287713375E-01
				.116266411E-02
				.170582129E-02
201	.166372096	1888.2930	1237.7485	.116726330E+01
				.338339670E-01
				.322063950E-01
				.130614559E-02
				.192555669E-02
202	.165938030	1893.2325	1235.2904	.116476040E+01
				.359426066E-01
				.353551864E-01
				.144021176E-02
				.213357431E-02
203	.165502546	1898.2141	1232.5506	.116451106E+01
				.367220753E-01
				.376036622E-01
				.154010689E-02
				.229289196E-02
204	.165064638	1903.2500	1229.3924	.116747086E+01
				.360778860E-01
				.384355714E-01
				.158442755E-02
				.237081088E-02

205	.164623046	1908.3553	1225.7860	.117373055E+ .340530194E- .377186949E- .156651953E- .235613472E-
206	.164176603	1913.5447	1221.8244	.118244857E+ .311043072E- .357411008E- .149820058E- .226501685E-
207	.163724531	1918.8283	1217.6648	.119233874E+ .278486083E- .330918993E- .140122923E- .213022222E-
208	.163266517	1924.2112	1213.4534	.120225181E+ .247870245E- .303094250E- .129633492E- .198483045E-
209	.162802616	1929.6942	1209.2873	.121145372E+ .222071103E- .277688293E- .120492775E- .185261465E-
210	.162333103	1935.2754	1205.2146	.121960155E+ .202175172E- .256657723E- .112954824E- .174696171E-
211	.161858349	1940.9519	1201.2527	.122659965E+ .188241642E- .242736214E- .127586271E- .167400676E-
212	.161378753	1946.7201	1197.4025	.123246541E+ .179929618E- .230236563E- .124507956E- .163620844E-
213	.160894714	1952.5767	1193.6618	.123724229E+ .176a724891E- .224468702E- .123766658E-

				.163494485E-02
214	.160406628	1958.5180	1190.0304	.124095334E+01 .178862029E-01 .223971555E-01 .185436039E-02 .167208106E-02
215	.159914900	1964.5403	1186.5127	.124358032E+01 .185922367E-01 .228625234E-01 .189668624E-02 .175081534E-02
216	.159419964	1970.6394	1183.1193	.124525920E+01 .196318852E-01 .238679408E-01 .196713075E-02 .187602272E-02
217	.158922296	1976.8105	1179.8650	.124529047E+01 .216522921E-01 .254501964E-01 .206893120E-02 .205387278E-02
218	.158422429	1983.0479	1176.7652	.124417902E+01 .240945355E-01 .276403318E-01 .224519912E-02 .229865201E-02
219	.157920935	1989.3453	1173.8251	.124171829E+01 .271757570E-01 .304243712E-01 .247680956E-02 .258910056E-02
220	.157418369	1995.6964	1171.0198	.123915144E+01 .307978842E-01 .336722459E-01 .273637171E-02 .294172199E-02
221	.156915119	2002.0969	1168.2659	.123419582E+01 .346555216E-01 .370416891E-01 .299245176E-02 .332075267E-02
222	.156411172	2008.5475	1165.3998	.123120141E+01

				.381571676E-01
				.399182509E-01
				.218526295E-01
				.367018579E-02
223	.155905860	2015.0575	1162.1999	.123094602E+01
				.425267784E-01
				.415220380E-01
				.231155423E-02
				.391277156E-02
224	.155397791	2021.6456	1158.4797	.123486940E-01
				.410395024E-01
				.412570314E-01
				.233366421E-02
				.398197864E-02
225	.154885152	2028.3369	1154.2004	.124317673E-01
				.396294954E-01
				.390961274E-01
				.224492603E-02
				.386223215E-02
226	.154366277	2035.1548	1149.4934	.125469356E+01
				.367732983E-01
				.356150021E-01
				.207411514E-02
				.359878706E-02
227	.153840097	2042.1156	1144.5687	.126763867E+01
				.332573894E-01
				.316274918E-01
				.186633965E-02
				.326681375E-02
228	.153306237	2049.2269	1139.6067	.128250958E+01
				.297604630E-01
				.277946890E-01
				.166035847E-02
				.293276608E-02
229	.152764823	2056.4896	1134.7133	.129944161E+01
				.266832811E-01
				.244904679E-01
				.147898588E-02
				.263724575E-02
230	.152216242	2063.9011	1129.9301	.130311164E+01
				.241839552E-01
				.218068057E-01
				.133120777E-02
				.239671703E-02

231	.151660962	2071.4577	1125.2613	.131250716E+01 .222780186E-01 .197619878E-01 .121794865E-02 .221492410E-02
232	.151099447	2079.1556	1120.6960	.132374275E+01 .209201847E-01 .192830261E-01 .113676427E-02 .206883211E-02
233	.150532113	2086.9917	1116.2199	.132795624E+01 .202514735E-01 .173208795E-01 .109455347E-02 .201434879E-02
234	.149959338	2094.9630	1111.8215	.133426104E+01 .196211666E-01 .167604348E-01 .105684453E-02 .196846223E-02
235	.149381466	2103.0672	1107.4944	.133972791E+01 .190595234E-01 .162277073E-01 .102633138E-02 .191031007E-02
236	.148798830	2111.3020	1103.2378	.134437972E+01 .185565047E-01 .157516821E-01 .998306322E-03 .186170130E-02
237	.148211769	2119.6648	1099.0567	.134819175E+01 .180714156E-01 .153164383E-01 .971464295E-03 .181746747E-02
238	.147620654	2128.1525	1094.9626	.135109052E+01 .176156479E-01 .149201922E-01 .947607993E-03 .177957966E-02
239	.147025903	2136.7613	1090.9722	.135296844E+01 .171911472E-01

				.202932111E-01 .133192142E-02 .265813606E-02
240	.146428000	2145.4863	1087.1257	.135369688E-01 .255734194E-01 .224695997E-01 .148775758E-02 .320900634E-02
241	.145827492	2154.3212	1083.3824	.135317807E+01 .261358738E-01 .252677090E-01 .168902020E-02 .346334488E-02
242	.145224968	2163.2593	1079.8087	.135144340E+01 .311222237E-01 .286953982E-01 .193815270E-02 .413257064E-02
243	.144620962	2172.2941	1076.3583	.134882988E+01 .343349881E-01 .326345521E-01 .222933835E-02 .470456707E-02
244	.144015772	2181.4226	1072.9455	.134613971E+01 .373873422E-01 .357432672E-01 .254124475E-02 .544591224E-02
245	.143409211	2190.6491	1069.4289	.134481616E+01 .396783784E-01 .404021020E-01 .285215279E-02 .616171272E-02
246	.142800351	2199.9894	1065.5397	.134654934E+01 .405562724E-01 .426302730E-01 .314652604E-02 .673467738E-02
247	.142187536	2209.4712	1061.1708	.135254644E+01 .396842526E-01 .434262759E-01 .313811792E-02 .753187191E-02

248	.141568761	2219.1285	1056.2721	.1362772851E+01 .3717914371E-01 .4212287451E-01 .3296334041E-02 .7682148341E-02
249	.140942270	2228.9925	1050.9633	.1375976911E+01 .3373917561E-01 .3942167161E-01 .2951472051E-02 .6971344621E-02
250	.140306980	2239.0851	1045.4336	.1390437211E+01 .3408997761E-01 .3827341931E-01 .2754400791E-02 .6534356691E-02
251	.139662538	2249.4168	1039.8502	.1404729971E+01 .3678696031E-01 .3479291731E-01 .2551631661E-02 .6174387021E-02
252	.139009124	2259.9922	1034.3201	.1418213911E+01 .3411795941E-01 .3079219661E-01 .2374622281E-02 .5865712371E-02
253	.138347209	2270.8031	1028.8963	.1429929331E+01 .3217326261E-01 .2744649871E-01 .2238657641E-02 .5651191341E-02
254	.137677379	2281.8513	1023.6000	.1440388761E+01 .3094392661E-01 .2574424241E-01 .2150503121E-02 .5553716501E-02
255	.137000250	2293.1291	1018.4404	.1449405661E+01 .3039283031E-01 .2468086241E-01 .2112656781E-02 .5587974341E-02
256	.136316448	2304.6321	1013.4263	.1456992651E+01 .3049367061E-01 .2484163211E-01

				.2127001791E-02
				.5765902216E-22
257	.135626616	2316.3541	1008.5741	.1463106661E+01
				.2124870?7E-01
				.2442503?8E-01
				.2196712391E-02
				.5117?0836E-22
258	.134931451	2328.2879	1003.9127	.1467632151E+01
				.2269399881E-01
				.2525193?6E-01
				.2327?5767E-02
				.6662040?3E-02
259	.134231737	2340.4246	999.4738	.1472377??7E+01
				.2489383691E-01
				.2675199?6E-01
				.2525125?0E-02
				.7442?6915E-02
260	.133528373	2352.7529	995.3?66	.1471149231E-01
				.2?917?0231E-01
				.2899299491E-01
				.2?977?144E-02
				.?0?231312E-02
261	.132822356	2365.2589	991.43?7	.1469872?91E-01
				.3177?656?E-01
				.3197873?51E-01
				.3146?9?36E-02
				.?0?3385?01E-02
262	.132114662	2377.9269	987.8463	.1466899791E+01
				.3?3166?61E-01
				.3539?5?961E-01
				.3554539931E-02
				.1153?9?59?E-01
263	.131405942	2390.7539	984.3853	.1463437911E+01
				.4103?37451E-01
				.3?9392?3?5E-01
				.3?751479?1E-02
				.1337?03421E-01
264	.130696019	2403.7401	980.7392	.1?6183591?E+01
				.4?9?711651E-01
				.417?64?3?1E-01
				.4316?73?31E-02
				.1?2?30?32E-01

265	.129983376	2416.9188	976.4738	.146525062E+01 .469543097E-01 .427944372E-01 .447633001E-02 .162663150E-01
266	.129265173	2430.3473	971.2652	.147522006E+01 .462559175E-01 .415999468E-01 .438241936E-02 .166167381E-01
267	.128538102	2444.0945	965.1266	.149121911E-01 .431339718E-01 .384594818E-01 .426448311E-02 .161292101E-01
268	.127799573	2458.2184	958.3822	.151128261E-01 .386513681E-01 .343307311E-01 .362355696E-02 .151654698E-01
269	.127048349	2472.7536	951.4273	.153174833E-01 .339561347E-01 .3[illegible]19169924E-01 .316665785E-02 .139274597E-01
270	.126284389	2487.7126	944.5477	.155130343E+01 .297970732E-01 .266551693E-01 .276229783E-02 .128819896E-01
271	.125508352	2503.2945	937.8912	.156885613E+01 .264917273E-01 .239672120E-01 .243630524E-02 .121264337E-01
272	.124721191	2518.8924	931.5203	.158415769E+01 .240978836E-01 .221693243E-01 .219813926E-02 .117365485E-01
273	.123923950	2535.0973	925.4726	.159715785E+01 .225751849E-01 .212397385E-01 .213576276E-02

				.117618779E-01
274	.123117726	2551.6981	919.7919	.162774926E-01 .216826745E-01 .211797666E-01 .194413966E-02 .122701630E-01
275	.122303747	2568.6806	914.5814	.161558553E-01 .220310792E-01 .220646492E-01 .191922128E-02 .133847044E-01
276	.121483529	2586.0235	912.2222	.161991698E-01 .231164474E-01 .240835656E-01 .195992624E-02 .153291365E-01
277	.120659138	2603.6923	906.4239	.161939707E-01 .253436654E-01 .275765315E-01 .276685592E-02 .154992624E-01
278	.119833554	2621.6302	904.3056	.161193[illegible] .[illegible] .332293725E-01 .224340981E-02 .235175[illegible]
279	.119011027	2639.7492	904.3796	.159523755E+01 .344246784E-01 .[illegible] .[illegible] .313333544E-01
280	.116196866	2657.9323	907.2595	.156516116E+01 .[illegible] .5[illegible] .259683434E-02 .[illegible]
281	.117395322	2676.0799	912.9244	.153727657E-01 .461579434E-01 .577746583E-01 .243562687E-02 .589723829E-01
282	.116603756	2694.131[illegible]	931.0382	.148670992E-01 .441792699E-01 .549[illegible] .167289594E-02 .958046740E-01

IV. PLMODE: DOCUMENTATION

The following chapter is extracted from the computer model PLMODE.

PLMODE ARL:UT NORMAL MODE BASED PROPAGATION LOSS MODEL
VERSION 1.2 MARCH 1980

DESIGNED AND IMPLEMENTED BY

SUSAN G. PAYNE

DOCUMENTATION FOR PLMODE IS GIVEN IN

THE ACOUSTIC NORMAL MODE MODEL NEMESIS

BY

RUTH GONZALEZ AND KENNETH E. HAWKER

ARL:UT TECHNICAL REPORT ARL-TR-80-13

AND

USER'S MANUAL FOR NEMESIS AND PLMODE

BY

RUTH GONZALEZ AND SUSAN G. PAYNE

ARL:UT TECHNICAL MEMORANDUM ARL-TM-80-6

APPLIED RESEARCH LABORATORIES

THE UNIVERSITY OF TEXAS AT AUSTIN

SPONSORED BY NORDA CODE 520, NSTL STATION, MISSISSIPPI 39529

OBJECTIVE

USING NORMAL MODE THEORY, THIS MODEL IS DESIGNED TO COMPUTE MODE ATTENUATIONS, COMPLEX VELOCITY POTENTIAL, COHERENT AND INCOHERENT PROPAGATION LOSS, AND PHASE IN A RANGE-INVARIANT ENVIRONMENT.

PHYSICAL DESCRIPTION

PLMODE IS A COMPUTER PROGRAM DESIGNED FOR USE WITH THE ARL:UT NORMAL MODE MODEL, NEMESIS. THIS MODEL ASSUMES A HORIZONTALLY STRATIFIED DEEP OCEAN WITH SINGLE CHANNEL PROFILES AND MULTIPLE FLUID SEDIMENT LAYERS OVERLYING A SUBSTRATE. SOUND SPEEDS IN THE WATER AND SEDIMENT LAYERS VARY WITH DEPTH. THE DENSITY IS CONSTANT WITHIN EACH LAYER. THE LAST LAYER IS A HOMOGENEOUS, SEMI-INFINITE FLUID OR SOLID SUBSTRATE, I.E., THE COMPRESSIONAL AND SHEAR WAVE SPEEDS AND DENSITY REMAIN CONSTANT WITH DEPTH. SOUND SPEEDS AND DENSITIES CAN BE DISCONTINUOUS AT LAYER INTERFACES. THE ATTENUATIONS IN THIS ENVIRONMENT ARE DEFINED IN PLMODE. ATTENUATION IN THE WATER AND THE SHEAR AND COMPRESSIONAL WAVE ATTENUATIONS IN THE SUBSTRATE ARE ASSUMED TO REMAIN CONSTANT WITH DEPTH. COMPRESSIONAL WAVE ATTENUATION IN THE SEDIMENT LAYERS CAN VARY WITH DEPTH, AND CAN BE DISCONTINUOUS AT THE LAYER INTERFACES.

MATHEMATICAL DESCRIPTION

PLMODE REQUIRES INPUT FROM THE MODE MODEL IN ORDER TO OBTAIN THE EIGENVALUES (KN), THE EIGENFUNCTIONS (UN(Z)),AND THE ATTENUATION TERMS IN EACH LAYER (GNL).

THE ATTENUATION TERMS ARE COMPUTED BY AN INTEGRAL DERIVED FROM FIRST ORDER PERTURBATION THEORY (SEE ARL-TR-80-13), ASSUMING THAT THE ATTENUATION IS CONSTANT IN EACH LAYER. IN PLMODE, IT IS ASSUMED THAT THIS IS TRUE IN THE WATER (AW, THE ATTENUATION VALUE IN THE WATER) AND THE SUBSTRATE (AC AND AS, THE COMPRESSIONAL AND SHEAR WAVE ATTENUATIONS, RESPECTIVELY). HOWEVER, THE ATTENUATIONS MAY VARY WITH DEPTH IN THE SEDIMENT LAYERS (AL(Z)).

IF THE SEDIMENT ATTENUATIONS ARE CONSTANT IN EACH LAYER THE MODE ATTENUATION FOR MODE NUMBER N IS COMPUTED AS

$$\sum_{L} (A_L * G_{NL}) + A_W * G_{NW} + A_C * G_{NC} + A_S * G_{NS}$$

WHERE L REFERS TO A SEDIMENT LAYER, W THE WATER, C THE COMPRESSIONAL WAVE IN THE SUBSTRATE, S THE SHEAR WAVE IN THE SUBSTRATE, AND N THE MODE NUMBER.

IF THE SEDIMENT ATTENUATIONS VARY WITH DEPTH, THEN THE MODE ATTENUATION FOR MODE NUMBER N, ATN, IS COMPUTED AS

$$\sum_{L} (D_L * 2 * PI * F / K_N * INT_L) + A_W * G_{NW} + A_C * G_{NC} + A_S * G_{NS}$$

$$INT_L = \int_{DZ} U_N^2(Z) * A_L(Z) / C(Z)$$

WHERE DL IS THE DENSITY OF SEDIMENT LAYER L, F IS FREQUENCY, C(Z) IS THE SOUND SPEED AS FUNCTION OF DEPTH, AND INTEGRAL( )DZ IS THE INTEGRAL WITH RESPECT TO DEPTH.

SINCE THE ATTENUATIONS AW, AC, AS AND AL(Z) ARE INPUT IN DB/M/KHZ THE ATTENUATION SUMS, ATN, HAVE TO BE CONVERTED TO NEPERS/M BEFORE USE IN THE FIELD CALCULATIONS.

$$M_N = AT_N * (F / 1000.) * (LOG_E (10.) / 20.)$$

WHERE MN IS THE ATTENUATION OF THE NTH MODE, AND F IS THE FREQUENCY (IN HERTZ).

THE FOLLOWING EQUATION IS USED TO COMPUTE THE COMPLEX VELOCITY POTENTIAL (VP) FOR A GIVEN SOURCE DEPTH (ZS), GIVEN RECEIVER DEPTH (ZR) AT A RANGE, R,

$$I * PI * Q * D_S * SUM (H_N * U_N (Z_S) * U_N (Z_R) * EXP (-R * M_N))$$

$$Q = 10.^{(SL / 20.)}$$

$$H_N = H_0^1 (K_N * R)$$

WHERE DS IS THE DENSITY OF THE LAYER IN WHICH THE SOURCE LIES, SL IS THE SOURCE LEVEL (DB RE 1 MICROPASCAL AT 1 M), I IS THE COMPLEX NUMBER I, AND H01( ) IS THE HANKEL FUNCTION OF ORDER ZERO, FIRST KIND. THE HANKEL FUNCTION IS APPROXIMATED BY THE FIRST TERM OF THE ASYMPTOTIC EXPANSION,

$$H_0^1 (K_N * R) = SQRT(2 / (PI * K_N * R)) * EXP(-I * (K_N * R - PI / 4)) .$$

THE PROPAGATION LOSS (PL) IS COMPUTED BY

$$PL = -10. * LOG_{10} (ABS(VP)^2) + SL .$$

THE INCOHERENT PROPAGATION LOSS (IPL) IS COMPUTED FROM THE INCOHERENT SUMMATION OF THE MODE TERMS,

$$I * PI * D_S * SUM ((ABS(H_N) * U_N (Z_S) * U_N (Z_R) * EXP (-R * M_N))^2)$$

$$IPL = -10. * LOG_{10} (IMS)$$

WHERE IMS IS THE INCOHERENT MODE SUM.

THE PHASE IS COMPUTED FROM THE COMPLEX VELOCITY POTENTIAL.

$$\text{PHASE} = \tan^{-1}\left(\text{IM(VP)} \,/\, \text{RL(VP)} \right)$$

WHERE IM(VP) AND RL(VP) ARE THE IMAGINARY AND REAL PARTS, RESPECTIVELY, OF THE VELOCITY POTENTIAL.

THE MAXIMUM PROPAGATION LOSS IS SET AT 180 DB. IF THE COMPLEX FIELD IS ZERO, THE PHASE IS SET AT 10**99.

ON INPUT

THERE ARE TWO INPUT FILES REQUIRED BY PLMODE - A FORMATTED DATA FILE SUPPLIED BY THE USER, AND THE DISK/TAPE FILE CREATED BY THE NORMAL MODE MODEL NEMESIS.

LFDISK (TAPE1)

THIS IS THE DISK/TAPE FILE CREATED BY THE NORMAL MODE MODEL, NEMESIS. IT CONTAINS ALL THE RELEVANT INPUT DATA SUPPLIED TO NEMESIS TOGETHER WITH THE EIGENVALUES, GROUP VELOCITIES, ATTENUATION TERMS, AND NORMAL MODES. SEE THE DESCRIPTION OF THE FORMAT OF THIS FILE IN THE NEMESIS PROGRAM, OR IN SUBROUTINE INPMOD OF PLMODE.
THIS FILE IS READ BY ROUTINES INPMOD AND GETMOD.

LFINP (TAPE5, INPUT)

THIS IS THE USER-SUPPLIED DATA SET CONTAINING THE DESCRIPTION OF THE ATTENUATION IN THE ENVIRONMENT, AND THE SOURCE/RECEIVER/RANGE GEOMETRIES.
THIS FILE IS READ BY ROUTINES INATTN AND INPSRR.

THE FOLLOWING RESTRICTIONS ARE IMPOSED ON THE INPUT TO PLMODE:

(1) ALL DEPTHS ARE REFERENCED TO THE AIR-WATER INTERFACE, AND NONE CAN FALL IN THE SUBSTRATE.
(2) ATTENUATIONS MUST BE DEFINED FOR EACH LAYER THAT WAS SPECIFIED IN THE NORMAL MODE MODEL.
(3) FOR ATTENUATION PROFILES, ALL DEPTHS MUST BE IN ORDER OF INCREASING DEPTH. THERE MUST BE AT LEAST A DEPTH-ATTENUATION PAIR SPECIFIED ON THE UPPER AND LOWER INTERFACES OF A SEDIMENT LAYER. THE LAST DEPTH AT THE BOTTOM OF A LAYER MUST EQUAL THE FIRST DEPTH AT THE TOP OF THE NEXT LAYER.
THE MAXIMUM NUMBER OF DEPTH-ATTENUATION PAIRS IS 48.
(4) ALL ATTENUATIONS MUST BE INPUT IN DB/METER/KILOHERTZ.
(5) ALL DEPTHS MUST BE INPUT IN METERS, AND MUST BE GREATER THAN 0.
(6) ALL RANGES MUST BE INPUT IN KILOMETERS, AND MUST BE GREATER THAN 0.
(7) THERE ARE NO RESTRICTIONS ON THE NUMBER OF SOURCES, RECEIVERS, OR RANGES THAT CAN BE INPUT IN A DATA SET (BUT SEE -CURRENT LIMITS- BELOW)

INPUT TO PLMODE IS VIA FORMATTED READ STATEMENTS. EACH ITEM MUST BE POSITIONED IN THE CORRECT FIELD AS GIVEN BY THE FORMAT STATEMENT.

CARD NO	COLUMN NO OF CARD	DESCRIPTION OF DATA	FORMAT
1	1-80	HEADER INFORMATION USED TO DESCRIBE DATA	8A10
2	1-10	ATTENUATION IN THE WATER	F10.4
	11-20	COMPRESSIONAL WAVE ATTENUATION IN THE SUBSTRATE	F10.4
	21-30	SHEAR WAVE ATTENUATION IN THE SUBSTRATE	F10.4
IF SEDIMENT LAYERS WERE DEFINED IN NEMESIS: CARDS 3,4 ARE INPUT.			
3	1-4	DESCRIPTION OF THE TYPE OF ATTENUATION INPUT:	1A4
		CONS TO DENOTE CONSTANT ATTENUATION IN EACH SEDIMENT LAYER.	
		PROF TO DENOTE DEPTH-ATTENUATION DESCRIPTION FOR EACH SEDIMENT LAYER	
4A,B..		FOR CONSTANT ATTENUATION (CONS), ATTENUATION IN EACH SEDIMENT LAYER	
	1-10	ATTENUATION FOR FIRST SEDIMENT LAYER	F10.4
	11-20	ATTENUATION FOR SECOND SEDIMENT LAYER	F10.4
	....	....	F10.4
		FOR ATTENUATION PROFILES (PROF), DEPTH-ATTENUATION PAIRS. THERE MUST BE A PAIR DEFINED AT THE TOP AND BOTTOM OF EACH SEDIMENT LAYER	
	1-10	DEPTH	F10.2
	11-20	SEDIMENT ATTENUATION	F10.4
	21-30	DEPTH	F10.2
	31-40	SEDIMENT ATTENUATION	F10.4
	....	....	
5		BLANK CARD AN END-OF-FILE FOLLOWING CARD 5 INDICATES THE END OF THE DATA SET (NO SOURCE/RECEIVER/RANGE INPUT TO COME). CARDS 1-5-EOF CAN BE REPEATED FOR DIFFERENT SETS OF ATTENUATIONS TO COMPUTE MODE ATTENUATIONS ONLY.	

6	1-5	DESIGNATOR OF THE TYPE OF OUTPUT DESIRED, DEPTH — TO DENOTE FIELD. PROPAGATION LOSS .VS. DEPTH FOR EACH SOURCE/RANGE COMBINATION RANGE — TO DENOTE FIELD. PROPAGATION LOSS .VS. RANGE FOR EACH SOURCE/RECEIVER COMBINATION BOTH — TO DENOTE BOTH TYPES OF OUTPUT	1A5
7A,B..		SOURCE DEPTHS	
	1-10	SOURCE DEPTH	F10.2
	11-20	SOURCE DEPTH	F10.2
	...	...	
8		BLANK CARD	
9A,B..		RECEIVER DEPTHS. CAN BE INPUT AS INDIVIDUAL DEPTHS (E.G., 10. 1025.), OR, CAN BE INPUT AS TRIPLETS OF DEPTH INCREMENT (PRECEDED BY A NEGATIVE SIGN), START DEPTH AND STOP DEPTH (E.G., -10. 100. 2000.), OR, CAN BE INPUT AS COMBINATIONS OF THESE TWO FORMS OF INPUT (E.G., 1025. -10. 100. 2000. 10.)	8F10.2
10		BLANK CARD	
11		RANGES. CAN BE INPUT IN THE FORMAT DESCRIBED ABOVE FOR THE RECEIVERS.	8F10.2
12		BLANK CARD CARDS 6-12 CAN BE REPEATED TO INPUT DIFFERENT SOURCE/RECEIVER/RANGE DATA SETS CORRESPONDING TO THE ATTENUATION DATA SET INPUT ON CARDS 1-5. AN END-OF-FILE FOLLOWING CARD 12 INDICATES THE END OF THE ENTIRE DATA SET. THE NEXT CARD TO BE READ FOLLOWING AN END-OF-FILE HERE IS CARD 1.	

ON OUTPUT

LFOUT (TAPE6)

THIS IS THE PRINTED OUTPUT FILE. IT CONTAINS THE GEOACOUSTIC PROFILE DESCRIBING THE ENVIRONMENT, THE MODE ATTENUATION TABLE, THE COMPLEX VELOCITY POTENTIAL, COHERENT AND INCOHERENT PROPAGATION LOSS, AND PHASE FOR EACH SOURCE/RECEIVER/RANGE COMBINATION.
THIS FILE IS WRITTEN ON BY ROUTINES PLOUT, PLOUT1, PLOUT2, PLHEAD, PLPRNT, ALERT, AND ERROR.

THE CHARACTER STRINGS BOD AND EOD (BEGINNING AND END OF DATA) DELINEATE THE START AND END OF EACH TABLE OF OUTPUT. NOTE THAT WHEN THE PHASE OF THE ACOUSTIC FIELD IS INDETERMINATE (COMPLEX FIELD EQUALS ZERO), ITS VALUE IS SET AT 10**99. THIS NUMBER EXCEEDS THE OUTPUT FIELD PROVIDED FOR IN THE FORMAT, AND ON THE CYBER 171, ASTERISKS ARE OUTPUT.

THE FOLLOWING ERROR MESSAGES MAY BE PRINTED ON DETECTION OF AN INPUT OR EXECUTION PROBLEM:

ARRAY SIZE DIAGNOSTICS

INSUFFICIENT SPACE ALLOTTED TO ARRAY ITITLE IN MAIN PROGRAM
THE VALUE OF MAXTLE IN MAIN PROGRAM PLMODE IS TOO SMALL: IT MUST BE GREATER THAN OR EQUAL THE NUMBER OF WORDS IN THE FIRST RECORD ON THE NEMESIS OUTPUT FILE.

INSUFFICIENT SPACE ALLOTTED TO ARRAY BUF
THE DIMENSION OF ARRAY BUF IN SUBROUTINE INPMOD (NBUF) IS TOO SMALL: IT MUST BE GREATER THAN OR EQUAL TO THE MAXIMUM NUMBER OF LAYERS SPECIFIED IN NEMESIS AND THE NUMBER OF WORDS IN THE SECOND RECORD ON THE NEMESIS DISK FILE.

MAX NO. OF LAYERS ON MODE DISK .GT. NO. SET FOR THIS PROGRAM
THE VALUE OF MAXLAY IN MAIN PROGRAM PLMODE IS TOO SMALL: IT MUST BE GREATER THAN OR EQUAL TO THE MAXIMUM NUMBER OF LAYERS SPECIFIED IN NEMESIS.

INSUFFICIENT SPACE IN WORK ARRAY FOR MODES AND ATTENUATIONS
INCREASE THE DIMENSION OF WORK ARRAY (MAXWRK) IN MAIN PROGRAM PLMODE. SEE CURRENT LIMITS (BELOW) AS A GUIDE TO MAXWRK.

MAX NO. OF SVP PTS. ON MODE DISK .GT. NO. SET FOR THIS PROGRAM
THE VALUE OF MAXSVP IN MAIN PROGRAM PLMODE IS TOO SMALL: IT MUST BE GREATER THAN OR EQUAL TO THE MAXIMUM NUMBER OF SOUND SPEED PAIRS SPECIFIED IN NEMESIS.

INSUFFICIENT WORK SPACE WHEN ALLOCATING SPACE FOR ATTEN CALCS.
THE VALUE OF MAXWRK IN MAIN PROGRAM PLMODE IS TOO SMALL:
SEE CURRENT LIMITS (BELOW) AS A GUIDE TO MAXWRK.

INSUFFICIENT SPACE IN ATTENUATION ARRAYS: MUST BE .GE. LAYERS-2
INCREASE THE DIMENSION OF ATTSED, ATTDEP ARRAYS (MAXATT) IN MAIN
PROGRAM PLMODE TO AT LEAST NUMBER OF LAYERS - 2

OVERFLOW IN ATTEN ARRAY ON ASSIGNING ATTEN TO INTERFACES
INCREASE SIZE OF ATTSED AND ATTDEP ARRAYS (MAXATT) IN MAIN
PROGRAM PLMODE TO AT LEAST 2*NUMBER OF SEDIMENT LAYERS

INSUFFICIENT SPACE IN WORK ARRAY FOR SEDIMENT ATTEN CALCS
INCREASE THE DIMENSION OF THE WORK ARRAY (MAXWRK) IN MAIN
PROGRAM PLMODE. SEE CURRENT LIMITS (BELOW) AS A GUIDE TO
MAXWRK.

INPUT DIAGNOSTICS

ERROR DETECTED WHILE READING FROM MODE FILE
PROBLEM WITH THE MODE DISK FILE: CHECK THAT THE FILE HAS THE
CORRECT STRUCTURE, NUMBER, AND SIZE OF RECORDS.

EOF ENCOUNTERED WHILE READING WATER AND SUBSTRATE ATTENUATIONS

NEGATIVE WATER OR SUBSTRATE ATTENUATIONS DETECTED ON INPUT

EOF ENCOUNTERED WHILE READING SEDIMENT ATTENUATION TYPE

UNKNOWN SEDIMENT ATTENUATION TYPE DETECTED (CONS OR PROF ONLY)

EOF ENCOUNTERED WHILE READING SEDIMENT ATTENUATIONS

NEGATIVE SEDIMENT ATTENUATIONS DETECTED

EOF ENCOUNTERED WHILE READING ATTENUATION PROFILE

ZERO DEPTH FOUND IN ATTENUATION PROFILE
IF BOTH DEPTH AND ATTEN ARE ZERO, THIS MESSAGE WILL NOT OCCUR; IT
IS EXECUTED ONLY IF DEPTH IS ZERO AND ATTEN IS NON-ZERO.

OVERFLOW IN ATTEN ARRAYS; OR, BLANK CARD MUST FOLLOW ATTENS
INCREASE THE SIZE OF ATTSED, ATTDEP ARRAYS (MAXATT) IN MAIN
PROGRAM, OR REDUCE THE NUMBER OF PROFILE POINTS INPUT.
CHECK THAT A BLANK CARD FOLLOWS THE ATTENUATION INPUT

NEGATIVE VALUES DETECTED IN ATTENUATION PROFILE